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THE UNIVERSITY OF ALBERTA

PETROLOGY AND BASE METAL MINERALIZATION,
JANICE LAKE AREA, NORTHERN SASKATCHEWAN

by



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A THESIS

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "Petrology and Base Metal Mineralization, Janice Lake Area, Northern Saskatchewan," submitted by Ulrich Rath, B.Sc., in partial fulfillment of the requirements for the degree of Master of Science.

ABSTRACT

The thesis area lies within the confines of the Wollaston Lake fold-belt system of northern Saskatchewan. A correlation of the metamorphic rocks found in the Janice Lake area with other similar rocks found along this trend suggest that the Janice Lake assemblages provide a "link" between members of the previously established Daly Lake Group and Sandfly Lake Group.

The rocks of the thesis area (Janice Lake area) were probably deposited in an intracratonic basin or geosyncline and represent most likely a penecontemporaneous paralic facies of either the Daly Lake Group and/or Sandfly Lake Group respectively. Field evidence, supported by chemical analyses of representative specimens from the thesis area suggest that these rocks consisted originally of arkosic sediments, subgraywacke, and acidic volcanic rocks (?).

Most of the metamorphic rocks found in the vicinity of Janice Lake belong to the zone of low to intermediate grade rocks of regional metamorphism. This zone has recently been termed the greenschist-amphibolite transition facies. The presence of staurolite in some of the metamorphic rocks of the thesis area suggest that these rocks belong to either the kyanite-sillimanite facies series or to the low-pressure intermediate facies series of Miyashiro (1961).

The ore mineralization found to date in the Janice Lake area is of subeconomic grade. It consists primarily of chalcocite and native copper associated with minor bornite, covellite, and malachite. This mineralization is confined principally to the metaconglomeratic horizons associated with the

hornblende gneiss map unit. A comparison with similar economic deposits found in other parts of the world suggests that at least some of the mineralization present in the vicinity of Janice Lake may be of syngenetic sedimentary origin.

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I. INTRODUCTION

General Statement

Regional mapping by the Saskatchewan Department of Mineral Resources and by the Manitoba Department of Mines and Natural Resources has disclosed the presence of a major structural and lithological feature probably of Proterozoic age which trends from the edge of the Precambrian Shield in Saskatchewan in a northeasterly direction through Wollaston Lake and possibly on into Manitoba, for a total lateral extent of about 400 miles (see Fig. 1). This major feature has been termed the Wollaston Lake fold-belt system by Money (1968) and consists in its broadest confines of a series of coalescing fold belts of metamorphic rocks which are isoclinally folded, complexly faulted and bounded on their eastern and western margins by granitic rocks of uncertain origin and age.

Historically, economic interest in the Wollaston Lake trend centered around the radioactive occurrences of the Foster Lakes region. Radioactivity in this area is associated with two distinct modes of occurrence; in pegmatites of definite igneous affiliations and along intersections of major topographic lineaments.

The first recent interest in base metals came from the prospecting activities of E. Partridge who in the years 1953 to 1955 disclosed the presence of mineralized frost heave and glacial boulders which bore some lithological similarity to the rocks found along the confines of the Wollaston Lake trend. In the ensuing years more intense prospecting and participation by major mining companies disclosed the presence of numerous base metal occurrences which

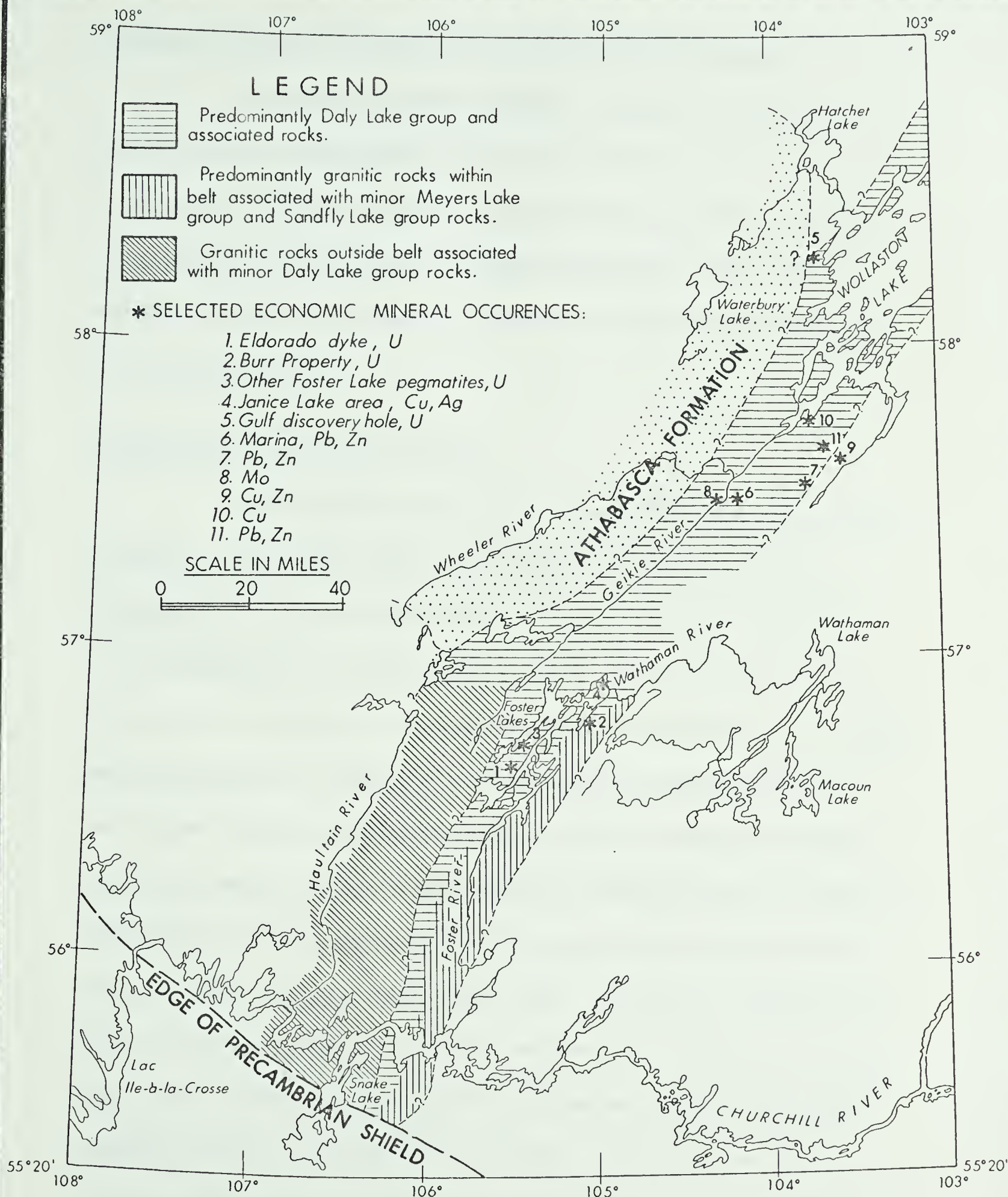


FIG. 1. Generalized Geology and Selected Economic Mineral Occurrences of the Wollaston Lake belt. (Geology modified from Money(1968). Can. J. Earth Sci., 6, p.1490.)

exhibited a variety of mineral parageneses and mode of occurrence.

This thesis is primarily intended as a study of the lithological assemblage and ore mineralization found in the vicinity of Janice Lake and aims to determine: (1) The nature of the metamorphic rocks; (2) The conditions of metamorphism; (3) The origin of the original sedimentary and/or volcanic assemblages, and (4) The nature and origin of the mineralization found within the metamorphic rocks.

Methods Utilized and Their Limitations

Detailed field mapping by the author of the Janice Lake area was supported by a petrographic study, selected chemical analyses, and by an investigation of selected polished sections. Numerous company files (Great Plains Development Ltd.) provided useful material, much of which has been incorporated into this thesis. The mapping procedure involved the use of vertical aerial photographs on a scale of 1":1/4 mile which, in conjunction with pace and compass traverses and lake shore geology, provided the basic information for the final map (in pocket). Where possible, aeromagnetic maps on a scale of 1":1 mile were used to delineate possible structural breaks using the interpretive principles suggested by Watanabe (1965). Samples were collected from most outcrops and an attempt was made to represent local variations in all rock types. The two major outcrops containing the base metal mineralization were sampled extensively using freshly blasted samples. As in other areas of the Canadian Shield certain limitations restricted the mapping project, such as the

absence of good marker horizons, extensive glacial overburden, and local sparsity of outcrops. No indications to the relative stratigraphic positions of each rock type were evident in the field and no contacts were seen.

In choosing samples for thin sectioning an attempt was made to select representative specimens of each major rock type. However, because of the marked lateral variation of these rock types along strike some specimens were chosen to allow for these variations within each map unit. Some of the biases inherent in the choice of specimens could be reduced by not over-emphasizing the mineralogical composition of any one sample. Instead, an attempt was made to delineate the significant compositional differences of each map unit in terms of their constituent rock types. The analytical petrographic methods used are described in Appendix I.

Six mineralized samples from both the Kaz Lake and Janice Lake occurrences were chosen for polishing. Here one of the principal difficulties encountered was the choice of samples to be used, as the mineralization is extremely fine grained and usually disseminated to such an extent to make positive identification in hand specimen difficult. Analytical techniques used are briefly described in Appendix I.

Because of the limitations imposed by time and facilities available, four samples were chosen for chemical analysis. These samples were chosen on the basis of hand specimen identification, in the belief that they probably represent

the "normal" of each particular rock type. Analyses were performed by Mr. A. Stelmack and the techniques used are briefly discussed in Appendix I.

Location and Physiography of the Thesis Area

The Janice Lake area lies approximately 120 airmiles north north-west of the village of La Ronge, Saskatchewan (Fig. 1). Thus the thesis area is located approximately at the intersection of latitude $56^{\circ}50'N$ and longitude $104^{\circ}56'W$.

The physiography of much of the Wollaston Lake belt is well exemplified by that found in the vicinity of Janice Lake. Typical of this area are large low lying regions of marsh and swamps associated with upland areas of subdued relief (Plate I, No. 1). Much of the area is covered by recent glacial deposits of sand and gravel. One esker, trending northeast, was noted south of the Watham River.

Although outcrops are relatively abundant in comparison to other immediate areas of the belt they do not comprise more than 15% of the total map area (map in pocket). Usually outcrops are small, well rounded and locally covered by lichen and moss thereby further restricting attempts at a more comprehensive mapping project.

Most of the area is covered by abundant vegetation ranging from mixed spruce and pine stands to areas covered almost exclusively by hardwoods such as birch. The only practical means of travel in the thesis area is by boat

along the numerous lakes and streams which seem to be at least in part structurally controlled; the Watham River and Janice Lake serve as two good examples of this.

Previous Work

The first work in the area was performed by Tyrrell in 1892 (Tyrrell and Dowling, 1896). He mapped the geology along his route from Lake Athabasca to Prince Albert via Wollaston Lake and the Foster Lakes. The Janice Lake area forms part of the north western corner of McMurchy's (1938) Foster Lake Sheet, (East Half), mapped on a scale of 1"-4 mi. More recently the Saskatchewan Department of Mineral Resources has mapped selected 15 minute quadrangles along the Wollaston Lake trend. These quadrangles and their approximate location given by the center of each map sheet are: the Middle Foster Lake Area (Mawdsley, 1957; $56^{\circ}40'N$, $105^{\circ}22'W$), the Barnett Lake Area (Money, 1961; $56^{\circ}23'N$, $105^{\circ}22'W$), the Needle Falls Area (Money, 1965; $55^{\circ}45'N$, $106^{\circ}W$), the Daly Lake Area (Money, 1966; $56^{\circ}37'N$, $105^{\circ}38'W$), the Nekweaga Bay Area (Chadwick, 1966; $57^{\circ}53'N$, $103^{\circ}53'W$), and the Morell Lake Area (Chadwick, 1967; $57^{\circ}37'N$, $103^{\circ}53'W$). Aeromagnetic map series on a scale of 1"-1 mi. were jointly published in 1962, 1963, and 1964 by the Saskatchewan Department of Mineral Resources and by the Geological Survey of Canada, over most areas covering the Wollaston Lake belt. Later, regional total intensity aeromagnetic maps on a scale of 1"-4 mi. were published covering most of northern Saskatchewan (Agarwal, 1962, 1965).

General Geology of the Wollaston Lake Belt

Because a minimum amount of data has been published on the Wollaston Lake trend it might be appropriate at this point to discuss first the general geology of the whole belt as recently given by Money (1968) and then subsequently to consider the general geology of the Janice Lake area. Money's description forms the basis for the following summary.

Regional mapping in northern Saskatchewan and Manitoba has disclosed the presence of a strong structural and lithological trend which in part conforms to the regional aeromagnetic patterns previously published. This Proterozoic feature has been termed the Wollaston Lake fold-belt system by Money (1968) and consists in its broadest confines of a series of coalescing fold belts of metamorphic rocks which are isoclinally folded, complexly faulted, and bounded at either side by granitic rocks. Three type sections of metamorphosed sedimentary and volcanic lithologies typical of this belt have been established to date. These sections were named by Money (1965, 1966) and are known as the Daly Lake Group, the Sandfly Lake Group, and the Meyers Lake Group respectively.

Of these, the Daly Lake Group appears to be the most widespread along the whole belt. The stratigraphic sequence within this group consists of interlayered biotite-cordierite-gneiss, biotite garnet-gneiss, and associated porphyroblastic biotite gneiss, biotite gneiss, arkosic metaconglomerate and meta-arkose, as well as minor quantities of hornblende-biotite-rocks and amphibolite, and calcsilicate assemblages. Some of these rocks still exhibit palimpsest sediment-

ary structures such as cross bedding (Chadwick, 1967). However, most of the rock types have been extensively metamorphosed and any indication to their original nature has been obliterated. Amphibolite facies metamorphism of the andalusite-sillimanite facies series is widespread along the belt. On the basis of chemical analyses it can be assumed that the Daly Lake Group consists of a series of metamorphosed pelites, arkose, and graywacke which might be typical of a miogeosynclinal assemblage. Relationships of the Daly Lake Group to the Myers Lake Group and the Sandfly Lake Group are uncertain and all that can be said with some degree of confidence is that these stratigraphic assemblages exhibit a different lithological sequence from that encountered in the Daly Lake Group.

The Sandfly Lake Group consists of interlayered meta-arkose; hornblende-biotite rocks and amphibolite, biotite-plagioclase rocks, and possible acidic meta-volcanics. It is felt that this lithological association represents a eugeosynclinal type of assemblage. The Meyers Lake Group which probably overlies the Sandfly Lake Group unconformably, consists of a basal quartz-pebble conglomerate and a sequence of quartzites and biotite-quartz-muscovite schists associated with a minor interlayered quartz-pebble conglomerate. It is assumed that this sequence of rocks is indicative of a stable shelf assemblage. All the metamorphic rocks of the Wollaston Lake trend have been intruded by various acidic and basic rocks ranging from minor dykes and sills to batholithic bodies.

Present indications are that the granitic rocks along the western margin of this belt are probably older (in part) than the metamorphic rocks forming

this fold-belt system. It is felt that these rocks, which are quartz monzonitic in composition, contributed in part to the metasediments found along the belt. Strong evidence for this comes from the compositional and textural similarities of larger cobbles and boulders found in some of the arkosic metaconglomerates and in the metaconglomeratic horizons of the Wollaston Lake metasedimentary sequence. Some of the "western granitic rocks" were remobilized during the Hudsonian orogeny (preliminary indications are that these rocks are about 2200 m.y. old) and may show local intrusive relations to the metamorphics of the belt. No convincing evidence exists as to whether all the granites along the eastern margin are younger or older than the rocks of the Wollaston Lake belt; however, it may be said with some degree of certainty that the "eastern granitic rocks" in the northerly regions of the belt are probably younger.

General Geology of the Janice Lake Area

The sequence of rocks found in the Janice Lake area (Fig. 2) consists of a series of massive hornblende-biotite rocks associated with interlayered metaconglomeratic horizons characterized by the presence of numerous deformed quartz pebbles and cobbles, and some "granitic" boulders. Associated with this hornblende-biotite-gneiss are several smaller units of laminated hornblende biotite gneiss, some quartzo-feldspathic rocks and minor quartzitic horizons. This series of rocks comprises one recognizable mapping unit and is hereby designated as unit A. Unit B, the second major recognizable map unit, consists essentially of a biotite gneiss intimately associated with a series of quartzo-feldspathic rocks

with varying mafic contents, as well as with some minor feldspathic and quartzitic varieties. Map unit A and map unit B are associated with several rock types of uncertain relationships. These are a series of calc-silicate rocks lying in the northwestern corner of the map area (M. W. Pyke, personal communication) and a series of hornblende-biotite-gneiss associated with a meta-volcanic (?) that lies in the southern portion of the map area. Several outcrops of a distinctly laminated mafic-rich meta-arkose were noticed in the eastern portion of the map area, this series of rocks does not conform to any of the other rock types found around Janice Lake and because of spacial and suggested compositional differences it is felt that these rocks may be part of another map unit.

One distinctly noticeable feature common to all the rocks found in the vicinity of Janice Lake is that no one unit is especially uniform across strike or along it. This divergence of compositional and textural aspects may reflect in part a rapid change of initial rock types deposited as thin interlayered sequences which together now comprise the major map units. A particularly noticeable effect of this characteristic is the apparently heterogeneous mixture of a quartz-rich "fraction" and a feldspar-rich "fraction" which together comprise most of the conglomeratic and non-conglomeratic hornblende-biotite gneiss. Another noticeable feature that may reflect some initial characteristics inherent in the rocks around Janice Lake is the restriction of certain minerals within individual layers, particularly within some of the feldspathic varieties of biotite gneiss. However, some caution is necessary in an interpretation which assumes that these peculiar features are "primary" as preliminary investigations of some of the rock

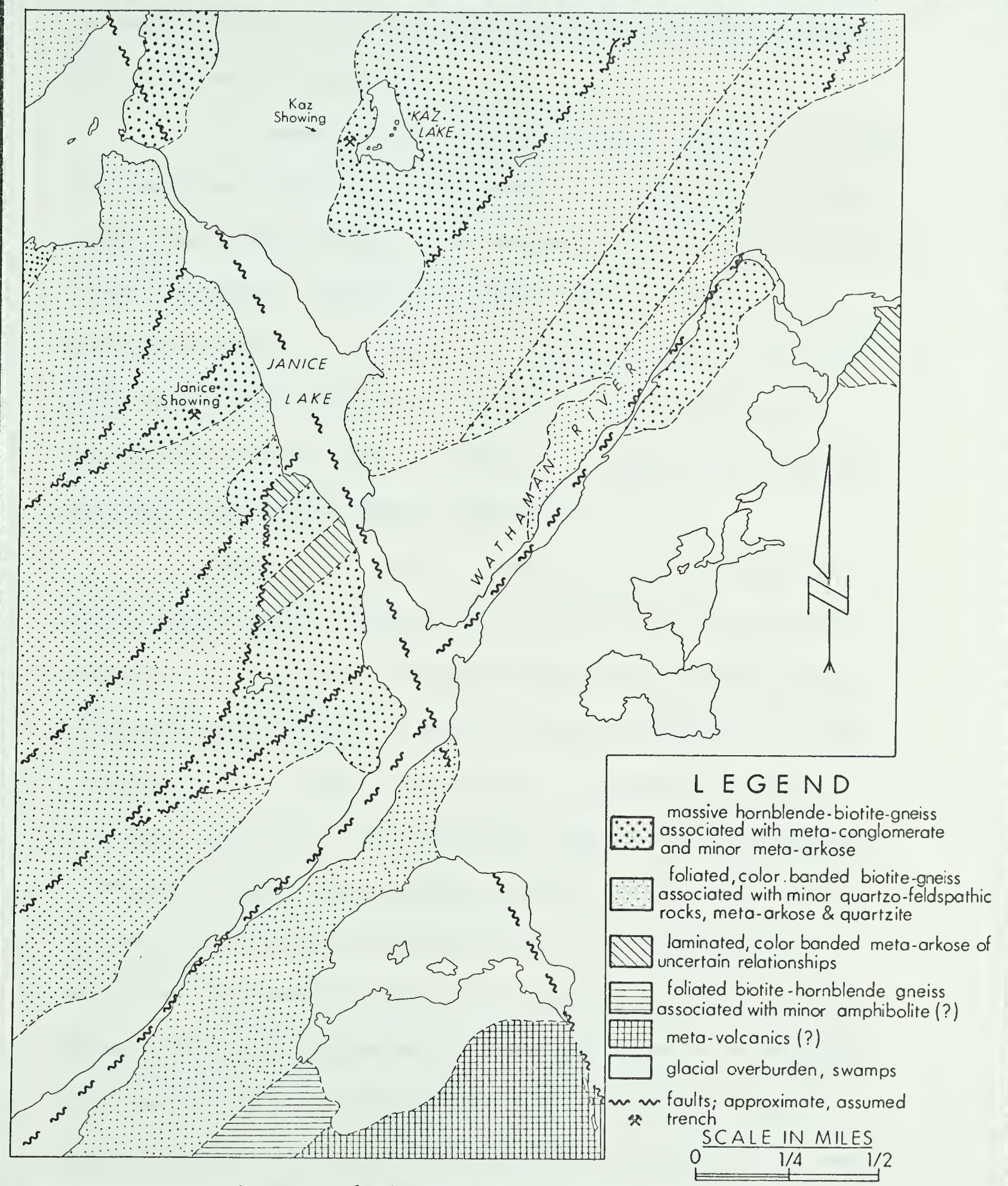


FIG. 2. Geology of the Janice Lake area.

types suggest that their compositional make-up has been modified by metasomatic effects or metamorphic segregation.

The presence of certain indicator minerals in the rocks of the Janice Lake area suggest that this region belongs either to the greenschist-amphibolite transition facies (Turner, 1968) or to the lower regions of the almandine facies of regional metamorphism. When the metamorphic rocks of the thesis area are classified in accordance to the facies series originally proposed by Miyashiro (1961), then the rocks around Janice Lake belong to the intermediate grade assemblages of either the kyanite-sillimanite facies series or to the low-pressure intermediate facies series of regional metamorphism.

Igneous activity within the Janice Lake area is confined to two periods of minor pegmatitic intrusion and an "earlier" period of granitic-"sill" intrusion (?). The early pegmatitic stage is suggested by the isolated presence of conformable quartz veinlets and pegmatites associated with some of the rocks in map unit A and B. Some of these pegmatites were apparently folded by a later stage of deformation. The second period of igneous activity is suggested by the presence of numerous disconformable pegmatites, particularly those associated with some of the hornblende-biotite-gneiss rocks on the southwestern shore of Janice Lake. The presence of several small, apparently conformable, granitic patches within the biotite gneiss north of Janice Lake suggest an earlier igneous event, possibly associated with the intrusion of the quartz veins of stage one. However, field relations are somewhat tenuous and further confirmation is needed.

Structurally, the area appears to have suffered isoclinal folding and has been faulted during at least two separate periods of deformation. These

faults are probably post-regional folding and metamorphism (Byers, 1962). The older event gave rise primarily to northeast trending faults and local evidence suggests that this period of deformation also gave rise to a series of infaulted blocks, later dissected by the well marked, sinistral, north-northwest trending lineaments. One of these infaulted blocks is the mineralized hornblende-biotite gneiss known as the Janice "showing".

The ore mineralization found within the map area is primarily restricted to those metaconglomeratic horizons associated with the massive hornblende-biotite gneiss. The mineralization consists of small grains of chalcocite, associated with minor bornite, covellite, and malachite together with finely disseminated lamellae of native copper. The spatial occurrence of the Janice Lake mineralization seems to be dominated by two controlling factors. Firstly, most of the chalcocite and native copper is concentrated within the feldspathic "fraction" of the metaconglomeratic horizons, and secondly, most of the native copper occurs along feldspar grain interfaces. Thus the distribution of these base metals is highly erratic and in general it may be assumed that most of the ore minerals are concentrated in roughly shaped, podiform bodies. These bodies may range in size from those of microscopic size to some in the order to ten's of feet in length.

Preliminary investigations suggest that the chalcocite mineralization may be syngenetic and that the native copper has been deposited by subsequent supergene activity. This assumption may be confirmed by the juxtaposition of the mineralized areas and major faults along which charged groundwater could easily circulate.

Table 1: Table of Formations

	Name	Comments
Recent and Pleistocene	Till, gravel, sand, silt, eskers	
Unconformity		
Precambrian	Vein quartz	Late pegmatite stage
	Intrusive Contact	
	Late pegmatites	May be in part younger than vein quartz
	Intrusive Contact	
	Acid meta-volcanic (?) and hornblende-biotite rocks	Rocks of uncertain stratigraphic position
	Relationship to other metamorphic rocks uncertain	
	Juno Lake meta-arkose	Rock of uncertain stratigraphic position
	Relationship to other metamorphic rocks uncertain	
	Early pegmatites, and "earlier" granite sills (?)	Tenuous field relationships
	Intrusive Contact	
		Map Unit B

Calc-silicate rocks	May belong to Map Unit B
Biotite gneiss, minor quartz- itic biotite gneiss, feldspathic biotite gneiss, and laminated biotite gneiss.	Map Unit B
Rocks may be interlayered in Unit B	
Hornblende-biotite gneiss , "minor meta-arkose," and quartzo-feldspathic varieties. Also some conglomeratic "horizons."	Map Unit A

Regional Correlation

Correlation with any other map units previously established is highly tentative because, (1) most of the Janice Lake rocks show a different grade of deformation accompanied by different mineral assemblages, (2) most of the Janice Lake rocks are intermediary types lying between compositions for other similar (?) rock types along the belt, and (3) the Janice Lake assemblage does not represent a complete cross-section across the belt, hence allowances for the presence of other possible map units must be made. With reference to Table II, a tentative correlation may be established between some of the Janice Lake rocks and members of the Daly Lake Group and Sandfly Lake Group respectively. This preliminary chart was established on the premise of the following criteria: (1) That the thesis area lies at the approximate northerly "junction" for the metamorphic rocks of the Daly Lake Group and the Sandfly Lake Group (Money, 1968, Fig. 1, p. 1490) and (2) That a review of previously published correlation charts of the various Wollaston Lake lithologies (Chadwick, 1966) suggests that the rocks of the thesis area occupy an intermediary position between members of the Daly Lake Group and Sandfly Lake Group respectively.

However, because no reliable evidence is available to accurately define the relationship between the Daly Lake Group and the Sandfly Lake Group and because the Daly Lake Group rock types appear to be more widespread along the belt than members of the other two groups (Money, 1968), it is felt that the Janice Lake rock types may represent a different sedimentary facies of the Daly

Daly Lake Group ①	Janice Lake Assemblage	Sandfly Lake Group ②	Comments
Calc.-silicate rocks ③ Hornblende-biotite rocks ④ and amphibolite Meta-arkose and quartzofeldspathic rocks; minor biotite-gneiss and granulite and calc-silicate rocks (usually rocks contain less than 10% mafic minerals) Arkosic meta-conglomerate ⑤ Biotite gneiss and granulite; minor meta-arkose; quartzofeldspathic rock; calc-silicate rocks, hornblende-biotite rocks, amphibolite, biotite-cordierite rocks, biotite garnet rocks, porphyroblastic biotite gneiss Biotite-cordierite rocks; biotite-garnet rocks, porphyroblastic biotite gneiss, minor biotite gneiss and granulite	Acidic meta volcanic (?) and hornblende-biotite rocks (Calc.-silicate rocks) ⑥ Biotite gneiss, minor quartzitic biotite gneiss, feldspathic biotite-gneiss, laminated biotite gneiss (MAP UNIT B) Hornblende-biotite gneiss, minor meta-arkose, quartzofeldspathic rocks, meta-conglomerate (MAP UNIT A) ⑦ Meta-arkose (Juno Lake)	Acidic meta-volcanic (?), minor interlayered hornbl. biotite gneiss and granulite Biotitic rocks; knobby biotite-plagioclase gneiss, minor anthophyllite-cordierite-biotite gneiss, biotite schist and gneiss, locally minor hblnd-bio. rocks. Hornblende-biotite gneiss and granulite, minor amphibolite, very minor biotite schist and gneiss. Meta-arkose, locally minor hornblende-biotite and biotite rocks, pebbly meta-arkose. ⑧	① After Money (1964). ② After Money (1962, 1963). ③ No correlation possible with Janice Lake calc. silicate rocks. ④ Scapolite rich, no correlation possible. ⑤ Matrix has an arkosic composition with low mafic mineral content. No correlation possible. ⑥ Rock of uncertain stratigraphic position (see comment 3) ⑦ Rock of uncertain stratigraphic position, no correlation possible ⑧ High muscovite content with associated sillimanite, no hornblende or biotite present. No correlation possible (see comment 7) Legend: --- good correlation --- possible correlation, may be different sedimentary facies no correlation possible

Table II.

Metamorphic Rocks Of The JANICE LAKE Area And Their Possible Correlations With Rocks In Other Areas Of The WOLLASTON LAKE Belt.

Lake assemblages that was probably deposited contemporaneously with rocks of this group. Some evidence is also present to concur with Money's (1968) suggestion that the Daly Lake Group and the Sandfly Lake Group may represent different sedimentary facies that were deposited penecontemporaneously (i.e. the Janice Lake assemblages seem to provide a link between the latter two groups).

II. DESCRIPTION OF THE METAMORPHIC ROCKS

Introduction

Most of the rocks found in the vicinity of Janice Lake may be categorized as belonging either to the hornblende-biotite gneiss group (map unit A), or as belonging to the biotite gneiss group (map unit B). These two groups (Fig. 3) are composed of a variety of similar rock types which are unified by the following characteristics: (1) spatial relationships within the map area, (2) textural similarities, (3) similar manner of occurrence in outcrop, and (4) similar mineralogical composition. There are, however, also some minor rock types found in the Janice Lake area which do not seem to conform to either of these two major map units. These rocks have been termed as rocks of uncertain stratigraphic position.

Field mapping and the follow-up by more detailed studies has led somewhat to the confusion of rock names as the names used in the field and on the maps do not always seem appropriate in the light of laboratory studies. It is the aim of this chapter to present a description of the metamorphic rocks occurring in the Janice Lake area in the hope of, (1) clarifying relationships between the various rock types, and (2) providing sufficient data to enable interpretative conclusions concerning these rocks. Such conclusions could be relevant to regional correlations with other rock types, similar to those found in the thesis area, which may be encountered elsewhere along the Wollaston Lake belt.

Selected samples have been chosen for each rock type and are identified in parentheses by their specimen number. The location of these samples is given

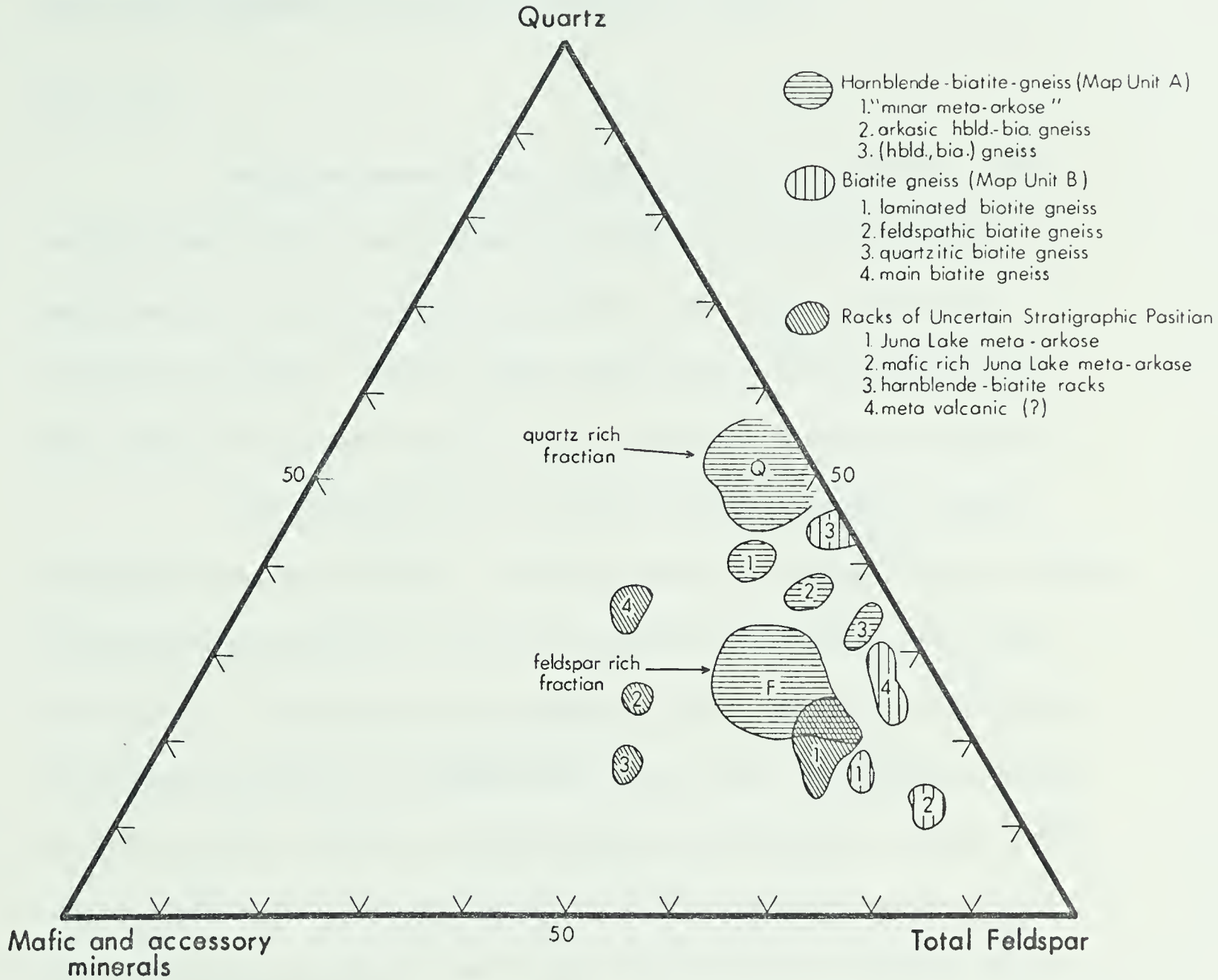


Fig. 3. MODAL ANALYSIS OF JANICE LAKE LITHOLOGIES

on the outcrop and specimen location map (in pocket). Modal analyses of all rock types encountered in the thesis area are given in Fig. 3.

Map Unit A

During the course of field mapping it became apparent that a wide variety of similar rocks, now designated as members of the hornblende-biotite gneiss map unit, existed as intimately associated units which tended to grade rapidly into each other. Certain similar features both in hand specimen and in thin section set these rocks apart from other recognizable units in the map area.

With reference to Fig. 4 it may be seen that map unit A consists essentially of two major divisions. The first of these encompasses the minor varieties which have been designated on the map (in pocket) by their field name, "minor meta-arkose." The second and more significant division consists of an assemblage of associated varieties of hornblende-biotite-gneiss rocks. Recognizable members of this latter division include a massive hornblende-biotite gneiss, locally containing metaconglomeratic horizons, a laminated hornblende-biotite gneiss, distinct from the "minor meta-arkose", and a series of related quartzo-feldspathic rocks.

General Characteristics

In outcrop, the hornblende-biotite gneiss is a massive rock which may, upon closer examination, show a local, weakly developed gneissosity. This rock usually exhibits a mottled dark green and grey on its weathered surface. This weathering characteristic apparently reflects the internal composition of the rock as the lighter areas are more quartz rich and the darker areas less quartz rich.

The rock is characteristically fine grained, hard, and has a visually estimated colour index of about 10-20. Associated with this massive variety are a series of minor, well-foliated hornblende-biotite gneisses of similar composition. These foliated types are found adjacent to presumed faults and their characteristic aphanitic nature, dark colour, and sometimes extreme hardness seems to indicate the effect of cataclastic deformation (Williams et. al., 1954). The "arkosic" varieties of hornblende-biotite gneiss are recognizable in the field by local areas showing faint brown laminations which seem to be more typical of the "minor meta-arkose." Thin section analysis show that these darker "layers" are essentially comprised of highly sericitized feldspar crystals. These laminated varieties are rarely of any extensive, mappable size. However, when they are associated with the "minor meta-arkose" they become more significant in terms of lateral extent. In hand specimen the "minor meta-arkose" weather to a tan, cream, or buff colour and show distinctive colour laminations which are often continuous across the outcrop. A comparison of modal analyses of these meta-arkose and the rocks found south of Juno Lake (meta-arkose of uncertain relationships) indicate that the Juno Lake meta-arkose is quite different. It often contains significant amounts of chlorite and up to 1% staurolite which are not found in the "minor meta-arkose" included in map unit A.

Minor Meta-Arkose

The term "minor meta-arkose" is rather an unfortunate one because of possible conflicts of names for rocks of a seemingly similar nature. However, it was first used by the author in the field to designate those minor sequences of rocks

which were intimately associated with the laminated hornblende-biotite gneiss varieties but different from them because of certain weathering characteristics and the presence of distinct colour laminations which were attributed by other workers (Money, 1961; Chadwick, 1966) to be characteristic of the meta-arkose generally encountered along the Wollaston Lake trend. Later mapping in the Juno Lake area disclosed the presence of similar rocks which, for want of a better name, were also called meta-arkose.

Modal analyses of two selected thin sections (R68-6, B-1) show a quartz content varying from 35% - 50%; a potassium feldspar content of 15%-22%, sodic plagioclase content of 25%-35%, as well as varying proportions of chlorite, amphibole, biotite, and opaque minerals which together total up to no more than 20%. The rock is also characterized by trace amounts of well rounded apatite crystals, sphene (as wedge shaped crystals or as overgrowths on the opaque minerals) and minor amounts of secondary calcite. Perhaps the most distinctive characteristic of this rock type is the occurrence of the major constituent minerals in definite layers which imparts the distinctive colour laminations to the weathered surface.

The quartz typically occurs as irregular strained crystals which form polycrystalline layers which may contain minor amounts of feldspar and mafic minerals. These layers weather to a distinctive cream colour. The potassium feldspar typically occurs as fresh medium-grained crystals which exhibit pericline-albite twinning. Some untwinned crystals were also seen, however these too were most likely microcline. The plagioclase feldspars are usually twinned on the Albite law and show noticeable effects of sericitization and minor saussuritization. Extinction angle measurements normal to the (010) section show values between

$3^{\circ} - 5^{\circ}$, hence the feldspar is probably sodic oligoclase (Kerr, 1959). The feldspars, plus significant amounts of biotite, amphibole, and opaque minerals together occur in layers which weather to a distinctive dark reddish brown colour.

The biotite occurs as irregular pleochroic crystals with general pleochroic effects from yellow to brown or dark green. Usually the edges are altered to chlorite. The amphibole occurs as highly irregular poikiloblastic crystals which often contain quartz and opaque minerals. On the basis of c to Z angles (on 010 sections) of $10^{\circ} - 21^{\circ}$, and the variation of pleochroic effects from yellow green to bluish green it would indicate that the mineral is probably common hornblende (Deer, Howie, and Zussman, 1966).

Laminated Hornblende-Biotite Gneiss

The field name originally given to this rock type was arkosic hornblende-biotite gneiss, some usage of this field name is still incorporated in the figures and illustrations accompanying this thesis. However, because this member of map unit A is distinguishable from its associates by the presence of faint, discontinuous color laminations it therefore seems more appropriate to use the name laminated hornblende-biotite gneiss rather than arkosic hornblende-biotite gneiss. This rock type typically occurs in small but recognizable areas that grade laterally into massive non-laminated hornblende gneiss or into the "minor meta-arkose." This tendency for a rapid lateral change may represent an intermediate rock type which lies between the other two. It therefore forms a connecting link between the "minor meta-arkose" and the massive hornblende-biotite gneiss and is thus one of the main reasons why the "minor meta-arkose" was included in map unit A.

Modal analyses from three typical thin sections (R68-9B, B-4, 4a) of the arkosic hornblende-biotite gneiss shows an average quartz content of 30%-42%, a potassium feldspar content of 20%-25%, a sodic plagioclase content of 30%-40%, and varying proportions of amphibole, biotite, and trace constituents which together total up to no more than 15%. As previously indicated, the significant textural quality of this rock is the incipient lamination suggested by the distribution of the main constituent minerals. Although far less confined in this distribution than the "minor meta-arkose," the occasional presence of a feldspar-rich layer will impart some orderly arrangement to the weathered surface.

Quartz typically occurs as polycrystalline aggregates of irregular strained crystals. These aggregates may be elongate but usually occur randomly dispersed throughout the slide. The potassium feldspar occurs as medium sized grains, which show the distinctive combined pericline-albite twinning and are probably microcline. Some untwinned crystals were also noted. Plagioclase feldspars occur as medium sized anhedral crystals, usually showing fine albite twin lamellae and a certain degree of alteration, particularly around the edges. Extinction angle measurements on the section normal to (010) show a variation from 3° - 7° . Most of the plagioclase grains are probably sodic oligoclase.

The mafic constituents of the rock are a strongly pleochroic biotite, an amphibole, and minor quantities of chlorite, opaque minerals, staurolite, garnet, apatite, and sphene. The biotite typically occurs as medium sized suboriented irregular grains which may impart a crude foliation to the rock. It varies in pleochroic intensity, but the usual effects are light brown to dark reddish brown. Some pleochroic haloes were noted in some of the crystals.

The amphibole present occurs as aggregates of small, poikiloblastic crystals intimately associated both with biotite and opaque minerals. Pleochroism varies from light green to bluish green and c to Z angles on the (010) section (varying from 15° - 21°) indicate that the mineral is most likely common hornblende.

The trace constituents of the rock consist of minor amounts of small rounded apatite crystals associated with minor quantities of sphene. The opaque minerals usually have irregular shapes although two cubic grains were also seen. Also present in these rocks are trace amounts of garnet and staurolite. The garnet occurs typically as red brown to brown poikiloblastic porphyroblasts or as small, isotropic grains. The staurolite, identified on the basis of its pleochroic effects ranging from colourless to pale yellow to yellow, its biaxial positive nature and parallel extinction (Deer, Howie, and Zussman, 1966), occurs either as poikilolitic porphyroblasts with quartz inclusions or as small grains. Some of these grains seem to be intimately associated with the hornblende present in this rock.

(Hornblende, Biotite) Gneiss

This series of rocks has been previously designated as the quartzo-feldspathic varieties of the hornblende-biotite gneiss map unit. Their only distinctive features are relatively lower total mafic content, a higher proportion of feldspar, an absence of colour laminated areas, and a modal composition that is very similar to some of those for other members of this map unit.

Modal analyses from two selected thin sections (B-2, B-3) shows a quartz content of 32%, a potassium feldspar content of 28%, a sodic plagioclase feldspar content of 34%, and a mafic mineral content of about 5% plus associated

minor quantities of apatite, zircons, and opaque minerals. Typically the minerals in this rock occur as an interlocking mosaic of medium sized anhedral crystals. No preferred orientation is indicated by any of the minerals present.

The quartz occurs as irregularly shaped grains which tend to be concentrated in randomly dispersed polycrystalline aggregates. The potassium feldspar occurs as medium sized anhedral crystals showing the typical microcline twinning. Most of the potassium feldspar present is probably microcline. The plagioclase feldspar occurs either as larger highly sericitized microporphyroblasts or as aggregates of medium sized interlocking grains. The grains show fine albite twin lamellae and extinction angle measurements on the section normal to (010) show a variation of values from 3° to 7° . Most of the plagioclase feldspars are probably sodic oligoclase. One myrmekitic intergrowth between a plagioclase feldspar grain and a quartz grain was noted.

The mafic minerals present consist of minor quantities of biotite, and hornblende. Some muscovite was also seen. All mafic minerals occur as randomly oriented crystals that have textural and optical properties similar to those found in the other members of this map unit.

Hornblende-Biotite Gneiss

This rock type is the principal constituent of map unit A. It predominates in its spatial occurrence over any of the previously mentioned minor varieties. Typically the hornblende-biotite gneiss occurs as a massive rock that shows very little lateral gradation on any one outcrop. The only noticeable change is the occasional presence of porphyroblastic areas (Plate IV, No. 1) within the

rock and the presence of pebbles, cobbles, and boulders which lie collectively within ill-defined areas throughout this rock type. These ill-defined areas have been termed "metaconglomeratic horizons" as they seem to represent discontinuous regions in which a coarse clastic "debris" forms a major constituent of the rock. The amount of clastic material varies from 10% - 20%. Modal analyses of the matrix comprising these metaconglomeratic horizons and of the non-metaconglomeratic hornblende-biotite gneiss indicate that they are the same.

Modal analyses of twenty-two selected thin sections (R68-1,5,R68-11 to R68-15, R68-17 to R68-23, R68-29 to R68-35, R68-36,46) show that the massive hornblende-biotite gneiss, both as a matrix within the metaconglomeratic horizons and as a non-metaconglomeratic variety, consists of a heterogeneous mixture of two discernible "fractions". These are a quartz-rich fraction, associated with feldspars and minor quantities of mafic minerals, and a feldspar-rich fraction, associated with some quartz and minor mafic minerals (see Fig. 4). Very few modal analyses of the hornblende-biotite gneisses fall between the average for these two fractions.

Mineralogically the constituent "fractions" of the hornblende-biotite-gneiss are the same, all that varies is the relative proportions of the various minerals present. The mean modal average for the quartz-rich fraction lies at about 48% quartz, 46% total feldspar, and 6% total mafic minerals plus associated trace constituents. The mean for the feldspar-rich fraction lies at about 28% quartz, 59% total feldspar, and 13% total mafic minerals and associated trace constituents. The ratio of potassium feldspar to plagioclase feldspar varies somewhat from 1:1.2 to 1:4.5.

The quartz occurs either as large polycrystalline aggregates (quartz-rich fraction) in which are found local "patches" of sericitized plagioclase grains, medium sized twinned (pericline-albite law) microcline grains, and a variable admixture of biotite, hornblende, and trace constituents. The quartz may also occur as smaller irregular grains which are usually randomly dispersed in an area consisting predominantly of larger sericitized sodic oligoclase grains (extinction angles on the section normal to (010) of 3° - 5°) and twinned microcline grains (feldspar rich fraction). These feldspars are associated with a higher content of brown, pleochroic biotite and a green to bluish green hornblende. The latter mineral occurs typically as irregular poikiloblastic grains. Some garnets were also seen in a few specimens. All other trace minerals have optical properties similar to those previously mentioned.

The metaconglomeratic "horizons" are characterized by the presence of several distinct varieties of coarse clastic material (Plate II, Nos. 2,3). With reference to Table III, it may be seen that two varieties of quartz pebbles and cobbles predominate over the other types of clastic material present.

A typical thin section from a "milky white" quartz cobble (R68-16) shows that 70% of the cobble consists of polycrystalline quartz, usually present as somewhat elongate masses. Randomly dispersed throughout this quartzitic "matrix" are patches of highly altered feldspar grains. Also present (up to 1.5%) are isolated crystals of chlorite after biotite, muscovite (usually associated with the feldspars), and highly altered amphibole grains. Some crystals of apatite, sphene, zircon and opaque minerals are also present. The mineralogical and textural make-up of

Table III

Description of the Coarse Clastic "Debris" found
in the Kaz and Janice Conglomerate "Horizons"

Description	Occurrence
(1) Hornblende rich pebbles, weakly foliated, very indistinct boundaries. (2) Large "granitic" boulders, sharp boundaries. (3) Quartz rich pebbles and cobbles, sharp boundaries, have a pitted clayey surface. (4) Milky white quartz rich pebbles and cobbles, distinct boundaries, are often highly contorted. No pitted surface.	Very rare, pebbles are very contorted, indistinct. May be contorted porphyroblasts (?). Several noted, usually associated with Nos. (3) and (4). Numerous, usually occur in well defined regions in the conglomeratic "horizon." Are associated with No. (4). Numerous, usually occur in well defined regions in the conglomeratic "horizons." Are associated with No. (3).

the second variety of quartz cobble (the "mottled" quartz cobble) is similar to that of the first variety, except for the apparently higher feldspar content. The "mottled" appearance is due to the extreme weathering and leaching-out of the feldspars.

Two sections from larger "granitic" boulders (R68-24,26) indicate that the mineralogical make-up of these corresponds to a granodiorite and a quartz monzonite respectively (Moorhouse, 1959). The first section (R68-26), that of the granodioritic boulder, has a modal content of 22% quartz, a potassium feldspar content of 12%, a plagioclase content of 56%, and a colour index of 10. The quartz typically occurs as strained crystals interstitial to the more dominant feldspar grains. The potassium feldspar occurs as smaller crystals which appear to be orthoclase (?), two microcline grains were definitely identified. The plagioclase feldspar occurs as highly sericitized grains with irregular boundaries. The mafic minerals are usually an association of brown pleochroic biotite and small green pleochroic hornblende grains. Some wedge-shaped sphene crystals, minor amounts of apatite and opaque minerals were also seen.

The second thin section (R68-24), that of the quartz monzonitic boulder, has a modal content of 11% quartz, 46% potassium feldspar, 40% plagioclase feldspar, and a colour index of 3. The quartz occurs as smaller grains; some polycrystalline aggregates were also seen. The potassium feldspar occurs as larger twinned microcline crystals which occasionally show myrmekitic intergrowths with quartz. The plagioclase feldspar is highly sericitized and definite identification of its composition is only tentative. The mafic minerals consist primarily of large poikiloblastic green hornblende grains which are associated with minor quantities

of biotite, chlorite, and opaque minerals. Some apatite and sphene grains were also seen.

Map Unit B

This map unit consists primarily of a biotite gneiss. Based upon textural criteria and on relative proportions of quartz to total feldspar content it is possible to recognize three minor varieties of this rock. These varieties are, a laminated mafic-rich biotite gneiss, a feldspathic biotite gneiss, and a quartzitic biotite gneiss (Fig. 5). Certain characteristics both in hand specimen and in thin section unify these rock types into one distinct recognizable group. These characteristics are (1) the usual absence of any amphibole (one rare occurrence of this mineral was recognized in a minor layer in a biotite gneiss), (2) all the biotite gneiss rocks show a distinct layering effect in hand specimen which is usually evident through the restriction of the opaque minerals into definite bands (Plate V, No. 2), (3) a uniform average mineralogical make-up which does not seem to vary between such extremes as those for the hornblende-biotite gneiss unit, (4) a low total mafic mineral content which generally does not exceed 10%, and (5) most of the rocks weather to a uniform buff or brown colour on the outcrop.

Laminated Biotite Gneiss

This rock type is the mafic-rich variety of the biotite gneiss map unit that shows recognizable colour laminations when polished as these laminations are not evident in outcrop (see Fig. 5, Plate V, No. 1). The presence of these bands is primarily due to the concentration of quartz and feldspar in alternate

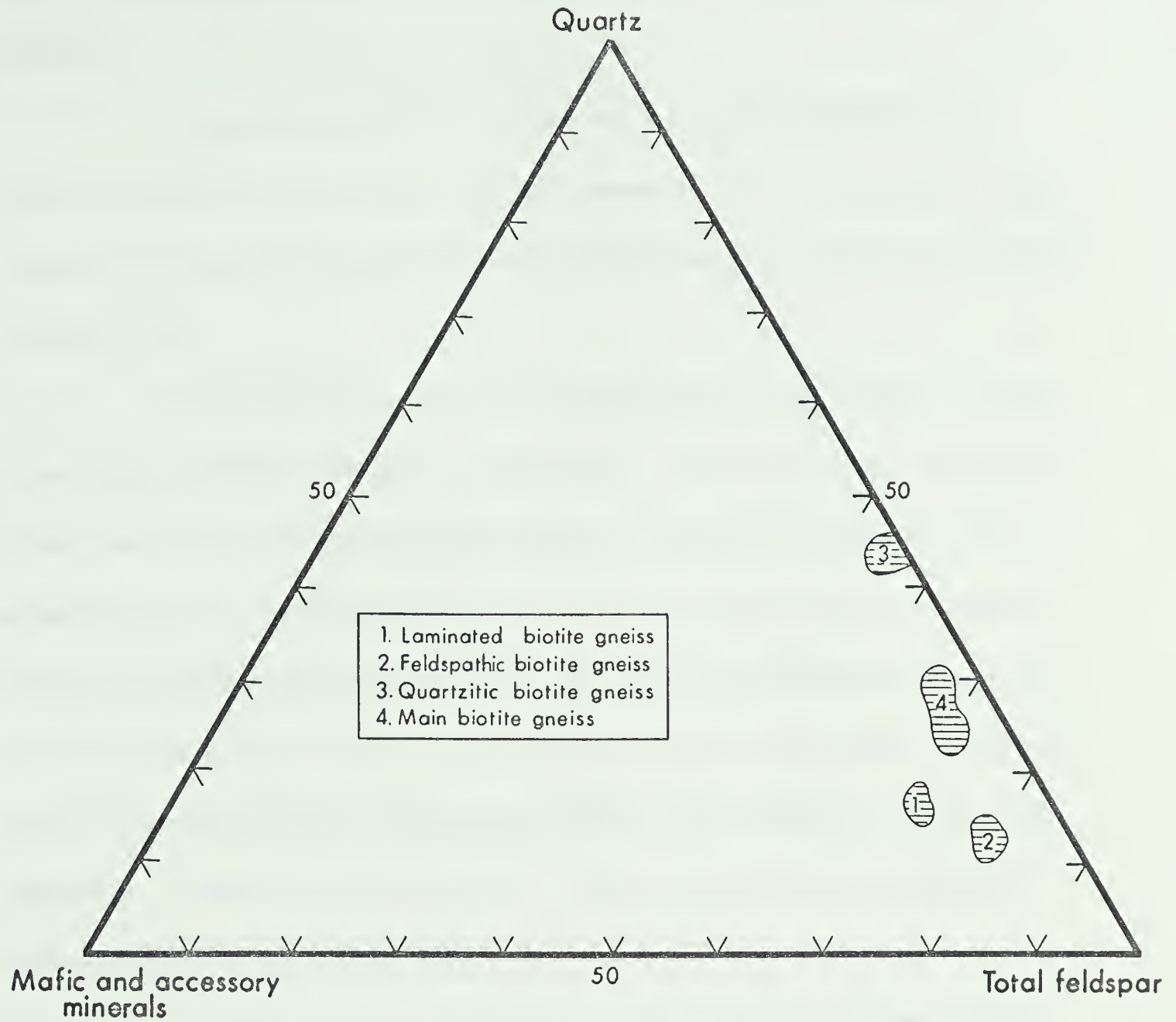


Fig.5. MODAL ANALYSIS OF MAP UNIT B.

layers. Some of these layers are also accentuated by the presence of opaque minerals.

A modal analysis from one selected thin section (R68-45) shows a quartz content of 18%, a potassium feldspar content of 53%, a plagioclase feldspar content of 16%, with biotite plus associated opaque minerals and trace constituents totaling to 13%.

The quartz occurs in layers as strained interlocking grains. The potassium feldspar exhibits two modes of occurrence. The first occurrence is as small distinct well twinned microcline grains with minor perthitic intergrowths. The second occurrence is as large porphyroblasts which show no traces of alteration. These porphyroblasts are also microcline. The plagioclase feldspar occurs as small sericitized grains which exhibit recognizable fine albite twin lamellae. Extinction angle measurements on the section normal to (010) give values of 3° to 5° . The plagioclase is probably sodic oligoclase. Some myrmekitic intergrowths of this feldspar and quartz were also noted.

The biotite occurs as pleochroic grains, usually in shades of light yellowish brown. These grains show a recognizable orientation parallel to the layering of the rock. The opaque minerals occur as small subrounded grains in distinct bands usually associated with biotite.

Feldspathic Biotite Gneiss

This rock type shows a slightly higher total feldspar content than the other varieties of the biotite gneiss map unit (see Fig. 5). Characteristically this variety lacks any colour laminations, however, the persistence of layering is still expressed by the occurrence of the opaque minerals in distinct bands.

A modal analysis from one selected thin section (R68-44A) shows a quartz content of 14%, a potassium feldspar content of 65%, a plagioclase feldspar content of 13%, and a total content of mafic minerals plus associated opaque minerals and trace constituents of 8%.

The quartz occurs as small distinct grains. No large polycrystalline areas were seen. The potassium feldspar occurs as irregular, twinned (pericline-albite law) grains of microcline. These grains have highly irregular shapes and often show corroded edges. Some perthitic intergrowths were also seen. The plagioclase feldspar occurs as small well-twinned (albite law) grains usually of an irregular shape. Extinction angle measurements normal to (010) show a range from 3° to 7° . Most of the plagioclase is probably sodic oligoclase.

The biotite occurs as randomly oriented small grains which are usually pleochroic in shades of brown and reddish brown. Most of these grains show some alteration to chlorite along their edges. Also present are minor quantities of muscovite, apatite and opaque minerals.

Quartzitic Biotite Gneiss

The quartzitic varieties of biotite gneiss are characterized by a distinctly higher total quartz content than is found in any of the other members of this group (Fig. 5). This quartzitic variety however, still shows all the other characteristics common to the whole map unit. This is, the presence of layering, usually accentuated by the occurrence of the opaque minerals in bands, and the characteristic weathering to a buff brown colour on the outcrop.

A modal analysis from one selected thin section (R68-38) shows a

quartz content of 44% , a potassium feldspar content of 16% , a plagioclase feldspar content of 38% , and a total content of mafic minerals and associated trace constituents of 2% .

The quartz occurs as distinct layers of polycrystalline aggregates. Most of the quartz shows a marked corrosion adjacent to feldspars. The potassium feldspar is microcline showing good pericline–albite twinning, commonly occurring as highly irregular shaped medium–sized grains. Most grains show some corrosion effects along their edges. The plagioclase feldspar exhibits two modes of occurrence. The first is as large porphyroblasts. These grains are all characterized by extensive sericitization. The second mode of occurrence of the plagioclase feldspar is as small interlocking grains, usually occurring in noticeable layers. These crystals show fine albite twin lamellae and extinction angle measurements normal to the (010) section give a range of values from 3° to 5° . Most of the plagioclase feldspar present in this rock is probably sodic oligoclase.

The mafic minerals and accompanying opaque minerals are a minor constituent of this rock. Recognizable are small biotite grains (usually partially altered to chlorite) and trace quantities of opaque minerals, rounded apatite grains, and muscovite.

Biotite Gneiss

The main member of map unit B, the biotite gneiss, includes all those similar rock types that are distinct from the previously mentioned varieties. That is, this group of rocks essentially consists of a fine to medium grained rock which shows faint layering, usually accentuated by the occurrence of opaque minerals

in these layers. In outcrop this biotite gneiss resembles all the other varieties, however, a thin section analysis shows that the average mineralogical composition is somewhat intermediate between the quartzitic and feldspathic varieties of biotite gneiss (see Fig. 5).

Modal analyses from three selected thin sections (R68-44B, B-5, 5a) show an average quartz content of 27%, an average potassium feldspar content of 53%, and an average plagioclase feldspar content of 16%. Mafic minerals and associated trace constituents total up to 4%.

The quartz occurs as medium sized anhedral grains. Most of the quartz present in these rocks occurs in quartz-rich layers, however, some of this mineral is also to be found in the feldspar-rich areas. No large polycrystalline masses of quartz were seen in these rocks. The potassium feldspar present occurs as interlocking grains concentrated primarily in the feldspar-rich layers. Most of the grains show pericline-albite twinning as they are probably microcline. The plagioclase feldspar occurs as altered smaller grains that may show some fine albite twin lamellae. Extinction angles measured on the section normal to (010) show a range of values from 6° to 8° . Most of the plagioclase present is probably sodic oligoclase.

The mafic minerals in these rocks are randomly dispersed. These minerals consist of a brown pleochroic biotite (usually altered to chlorite along the edges) and of minor amounts of muscovite. The opaque minerals in these rocks are associated with minor amounts of apatite and zircon which together seem to occur concentrated in faint layers.

Rock Types of Uncertain Stratigraphic Position

Introduction

During the course of field mapping it became apparent that some of the rock types found in the vicinity of Janice Lake seem to have certain characteristics that set them apart from the rock types included in map unit A and in map unit B respectively. Attempts to trace out the lateral continuation of these varieties to see if they might grade into any recognizable member of the two major map units failed. Although no contacts were seen between the rocks of uncertain stratigraphic position and members of the two map units, textural and spatial relationships suggest that these rock types are distinct from any other types found within the vicinity of Janice Lake (Fig. 6). Further field mapping in an attempt to complete a cross-section across the Wollaston Lake belt should clarify the position of some of these rock types.

Meta-arkose

The Juno Lake meta-arkose occurs in small outcrops south of Juno Lake. It is characterized by the presence of very distinct colour laminations which are present along the whole outcrop (Plate II, No. 1). A detailed examination of these laminations, however, shows that they are not continuous layers but rather occur as elongate elliptical traces that seem to be interlayered.

Modal analyses of four selected thin sections (JUN2, 3A, 3B and JUN 4) show that these rocks are feldspar-rich with a varying mafic mineral content which apparently subdivides this type of rock into a mafic meta-arkose and a feldspathic meta-arkose (Fig. 6).

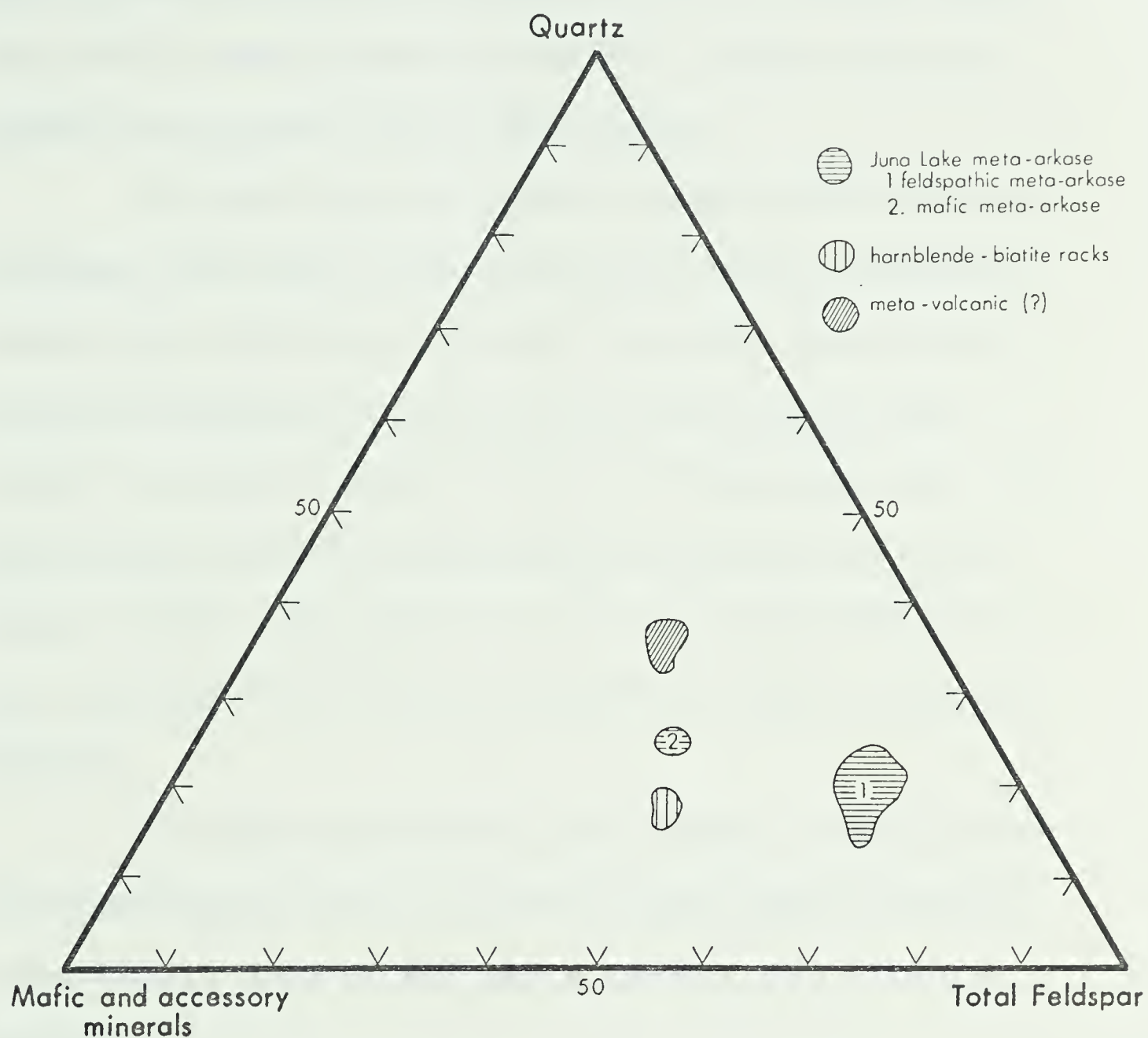


Fig. 6. MODAL ANALYSIS OF ROCKS OF UNCERTAIN STRATIGRAPHIC POSITION.

Feldspathic Meta-Arkose

Modal analyses of three selected thin sections (JUN 3A, 3B, and JUN 4) show that this variety has a quartz content of 22%, a potassium feldspar content of 25%, a sodic plagioclase content of 40%. The mafic minerals plus associated trace constituents total up to 13% of the rock.

The quartz occurs as polycrystalline aggregates which lie in layers. The feldspars, mafic minerals, and some minor quartz tend to be concentrated in alternating layers with the quartz-rich bands. The potassium feldspar occurs as small grains, sometimes altered microcline (showing typical pericline-albite twinning). The plagioclase feldspars tend to occur as large irregular grains. These grains are usually altered and characterized by the presence of fine albite twin lamellae. Extinction angle measurements on the section normal to (010) give a range of values from 4° to 6° . Most of the plagioclase feldspar is probably sodic oligoclase.

The mafic constituent of these rocks is chlorite. It usually occurs as irregular interstitial grains which lie between and around larger felsic minerals. Associated with the chlorite are small grains of pleochroic green to blue-green hornblende.

Also present in these rocks is a rather large variety of minor accessory minerals. The most significant of these is the occasional occurrence of staurolite. This mineral occurs as small pleochroic, yellow grains or as larger porphyroblasts which typically contain quartz as inclusions. Also present within these rocks are abundant opaque minerals, rounded apatite grains, and sphene. Small grains of garnets were noted in one slide (JUN 3A).

Mafic Meta-Arkose

Modal analysis of one selected thin section (JUN 2) shows a quartz content of 25%, a potassium feldspar content of 15%, and a plagioclase content of 30%. Mafic minerals and associated trace constituents present in this rock total up to 30%.

The quartz occurs as polycrystalline aggregates typically arranged in layers. Alternating with these quartz-rich layers are feldspar-rich and mafic-rich layers. The potassium feldspar occurs as small, irregular grains of microcline (showing typical pericline-albite twinning). Some of the potassium feldspar grains are untwinned and altered. The plagioclase feldspar occurs as medium sized irregular grains which are highly sericitized. Most of the grains show some fine albite twin lamellae. Extinction angle measurements on the section normal to (010) gave a range of values of 5° to 8° . Most of the plagioclase is probably sodic oligoclase.

The principle mafic mineral present in this rock is chlorite which occurs as abundant irregular grains usually surrounding the felsic minerals. Also found in this rock are small poikiloblastic grains of a bluish-green amphibole (var. common hornblende).

The trace constituents of this rock consist of significant amounts (1%) of a pleochroic staurolite (in weak shades of pale yellow to greenish yellow). Associated with the staurolite are small rounded grains of apatite and zircons. Opaque minerals are also present and tend to be disseminated throughout the rock rather than being restricted to layers.

Hornblende Biotite Rocks

These rocks occur in the southern portion of the map area where they are associated with a meta-volcanic (?) horizon. When mapped in the field these rocks were originally called "foliated biotite hornblende gneiss" (see Fig. 2). However, thin section examinations show that biotite predominates over hornblende. Thus the more correct name for this rock type is a hornblende biotite gneiss (Winkler, 1965, p. 209).

In outcrop this rock weathers to a typical black colour. The rock is fine grained, hard, and has a well developed foliation. Only two occurrences of this rock type were seen, one of these is believed to be a large boulder, however, the second occurrence is most definitely an outcrop (see outcrop and specimen location map in pocket).

A modal analysis of one selected thin section (R68-48) shows a quartz content of 18%, a potassium feldspar content of 15%, and a plagioclase feldspar content of 32%. The total mafic mineral content and trace constituents comprise 34% of the rock (Fig. 6).

The most noticeable characteristic of this rock is the extremely fine grained nature of the minerals present and the well developed foliation. A closer examination of the biotite shows that most of the grains have aggregate extinction. That is, most of the grains are oriented in such a manner as to show the strongest and weakest pleochroic absorption at the same position during a 360° rotation of the microscope stage. Also noticeable in this rock is the apparent segregation of quartz and feldspar into predominantly quartz-rich and predominantly feldspar-rich layers.

The quartz in this rock show two modes of occurrence. The first is as small highly irregular grains which are found in both the feldspar-rich layers and in the quartz-rich layers. The second occurrence of the quartz is as large elliptical polycrystalline aggregates which are randomly dispersed throughout the slide. The potassium feldspar occurs as small untwinned grains (recognized through staining), however, where twinning is apparent it indicates that at least some of the potassium feldspar in this rock is microcline. The plagioclase feldspar occurs as small usually well twinned grains. Some untwinned grains were also seen. Extinction angle measurements on the fine albite twin lamellae on the section normal to (010) give a value of 8° . Most of the plagioclase feldspar is probably sodic oligoclase.

As previously mentioned, the main mafic mineral present in this rock is a strongly pleochroic greenish biotite. Also present are large poikiloblastic grains of a bluish green pleochroic hornblende. These grains appear to occur in definite layers. The trace constituents of the rock consist primarily of small rounded apatite grains and a rather high content (3%) of opaque minerals. These opaque minerals tend to occur dispersed throughout the rock.

Meta-Volcanic (?)

When first mapped in the field these rocks showed an occurrence in outcrop very similar to that of known metavolcanics seen by the author in other areas of the Canadian Shield. The very fine grained, dense, and hard nature of the rock associated with the striking appearance of conformable quartz veinlets arranged in a parallel manner across the outcrop (Plate III, Nos. 2,3) suggested

that these rocks may be of a tuffaceous origin (?). Most of the outcrops show also a very fine layering effect.

Modal analyses of two selected thin sections (R68-50A, 50B) show an average quartz content of 38%, a potassium feldspar content of 17%, and an average plagioclase feldspar content of 20%. The total mafic mineral and trace constituent content is 25%.

The quartz occurs in definite quartz-rich layers formed by large interlocking polycrystalline aggregates of this mineral. Some small quartz grains were also seen in the feldspar rich layers. The potassium feldspar occurs both as small irregular grains and as the occasional larger porphyroblast. Most grains are untwinned, however, the presence of pericline-albite twinning on some grains suggests that at least some of the potassium feldspar present is microcline. The plagioclase feldspar occurs as small irregular grains showing fine albite twin lamellae. Extinction angles measured on sections normal to (010) give values of 8° . Most of the plagioclase present in this rock is probably sodic oligoclase.

The main mafic mineral present in this rock is a strongly pleochroic greenish biotite. No amphiboles of any kind were seen in this rock. However, some noticeable trace constituents, previously not seen in any of the other rocks, are epidote and allanite. The epidote occurs as weakly pleochroic (in shades of pale yellow and green yellow) grains which tend to lie together as larger aggregates in the quartz-rich layers. The epidote may be associated with biotite when it occurs as coronas around dark brown allanite crystals. The zircons found in this rock tend to occur in clusters of rounded grains that are somehow spatially related to the

epidote rich areas. Other constituents present in this rock are muscovite and some opaque minerals.

III CONDITIONS OF METAMORPHISM

Introduction

Money (1968), in a consideration of the regional metamorphic grade of the rocks found along the Wollaston Lake belt, suggests that most (if not all) of these rocks now belong to either the andalusite-sillimanite facies series or to the low-pressure intermediate facies series of regional metamorphism as proposed by Miyashiro (1961). Money states that although mineral assemblages belonging to the upper amphibolite facies of these series are widespread along the belt, mineral assemblages belonging to the lower amphibolite facies "are known to occur in limited areas," (Money, 1968. p. 1497). The mineral parageneses found in the rocks around Janice Lake suggest that this region may belong to the intermediate grade facies of either the kyanite-sillimanite facies series or of the low-pressure intermediate facies series of regional metamorphism.

The Facies Series

The concept of facies series was introduced by Miyashiro (1961) in order to account for the systematic mineralogical variations associated with different conditions of formation for various metamorphic regions of the world. His five proposed facies series include three standard types and two intermediate groups. These facies series arranged in order of increasing operating rock pressure (which Miyashiro regards as the one single most important determining factor) are: (1) andalusite-sillimanite type, (2) low-pressure intermediate group, (3) kyanite-sillimanite type, (4) high-pressure intermediate group, and (5) jadeite-glaucophane type. As the latter two series do not seem pertinent to a discussion of the

thesis area they will not be considered further.

Of these facies series, the kyanite-sillimanite group encompasses what was previously believed to be the "normal" or Barrovian type of regional metamorphism (Winkler, 1965). This standard group consists essentially of a green-schist facies, an epidote-amphibolite facies, and an amphibolite facies (Miyashiro, 1961). Each of these facies is characterized by the presence of the index mineral zones of chlorite to biotite to garnet to staurolite to kyanite to sillimanite as proposed by Barrow (1893, 1912, in Winkler, 1965) for the Grampian Highlands of Scotland. The most important determining factor originally believed to be responsible for this type of regional metamorphism is temperature (Fyfe, et. al, 1958). However, the concept of temperature being predominant in all types of regional metamorphism was later challenged by Miyashiro (1961) who believes that only some of the originally proposed index minerals may be found in more than one facies series and thus can only be used very tentatively as a basis for the identification of the type of regional metamorphism under investigation. After a careful survey of the petrographic descriptions available on the various metamorphic regions of the world, Miyashiro (1961) concluded that the kyanite-sillimanite facies series of regional metamorphism is recognizable by the presence of kyanite in low-grade rocks and sillimanite in high-grade rocks. Andalusite, glaucophane, and cordierite are absent, while staurolite and almandine may be present. Sodic plagioclase feldspars persist in pelitic rocks from the lowest facies (chlorite zone) to the highest facies (sillimanite zone).

The widespread occurrence of such indicator minerals as cordierite and

sillimanite, and the occasional occurrence of andalusite suggested to Money (1968) that most of the rocks found along the Wollaston Lake trend did not belong to the kyanite-sillimanite facies series but to the andalusite-sillimanite facies series of regional metamorphism. As originally proposed by Miyashiro (1961) this facies series is characterized by the stability of andalusite in low grade rocks and sillimanite in high grade rocks; kyanite, staurolite, and glaucophane are always absent. Other common minerals present are cordierite, pyrospite, and potassium feldspar. Sodic plagioclase may be present in basic rocks but will persist only in the low grade rocks (greenschist facies).

The low-pressure intermediate facies series of regional metamorphism lies between the andalusite-sillimanite type and the kyanite sillimanite group. As originally proposed by Miyashiro (1961), this facies series includes indicator minerals common to both the standard facies series. Typical of this intermediate type is the apparently stable occurrence of andalusite, cordierite, and staurolite in the same rocks. Here then, according to Miyashiro (1961), the operating rock pressures must have been intermediate between those for the two standard facies series. The limited occurrence of garnet amphibolites in close association with cordierite-bearing rocks are known from some parts of the Wollaston Lake belt and Money (1968) feels that this association is typical of the low-pressure intermediate group of regional metamorphism.

The Janice Lake Area

Before considering some of the implications suggested by certain metamorphic indicator minerals present in the rocks of the Janice Lake area, it seems

appropriate at this point to outline some of the more common mineral parageneses found within these rocks. However, because of the predominance of a certain number of these minerals in most of these rocks, it seems unnecessary to list each specimen studied from the thesis area. Rather, a list of significant mineral associations and one related specimen number in which these minerals occur will be presented. These specimens have been described in part II of this paper. For the location of the samples refer to the outcrop and specimen location map in the back pocket of this thesis.

As can be seen from the list presented in Table IV, sodic oligoclase, microcline, biotite and hornblende predominate in the various rock types. Associated with these main constituents are such other indicator minerals as garnets, muscovite (minor), epidote (minor), and staurolite. The implications suggested by the presence of some of these indicator minerals will now be considered.

The abundance of biotite in all the rocks of the thesis area suggests that this mineral may serve as a true indicator mineral (since it appears to be divorced from compositional influences). However, after a detailed analysis of certain indicator minerals to define metamorphic isograds, Atherton (1965) comes to the conclusion that the occurrence of biotite is in fact influenced by the composition of the original rock. Unless this composition is known with some degree of certainty, biotite becomes ineffective as a true indicator mineral. However, what can be said is that biotite, in general, will not occur in very low grade metamorphic rocks. The low grade rocks are usually typified by the presence of chlorite (Atherton, 1965).

Table IV

Typical Metamorphic Mineral Assemblages
from the Janice Lake Area

Mineral Assemblage	Specimen Number	Rock Type
Quartz-sodic oligoclase - microcline - biotite-hornblende-garnet	R68-1	Massive hbld.-bio. gn.
Quartz-sodic oligoclase-microcline- biotite-hornblende	R68-11	Massive hbld.-bio. gn.
Quartz-sodic oligoclase-microcline- biotite-hornblende-staurolite-garnet	R68-9B	Arkosic hbld.-bio. gn.
Quartz-sodic oligoclase-microcline- biotite-muscovite	R68-38	Quartzitic biotite gn.
Quartz-sodic oligoclase-microcline- chlorite-hornblende-staurolite-garnet	Jun 3A	Juno Lake meta-arkose
Quartz-sodic oligoclase-microcline- biotite-epidote-muscovite	R68-50A	Meta- volcanic (?)

The occurrence of chlorite in abundance in some of the metamorphic rocks of the thesis area does not seem to present a real problem. An analysis of the texture of the rocks which contain this mineral (Juno Lake meta-arkose) suggests that these rocks have been affected by cataclastic deformation accompanied by a retrogressive metamorphic effect (Williams, et. al., 1954). Thus chlorite is probably present as a pseudomorph after biotite in most of these rocks.

The occurrence of a bluish-green hornblende in some of the rock types of the thesis area suggest that it may be controlled by compositional effects, as it does not occur in one of the major map units at all. This is indeed the fact, and Leake (1965) in an investigation of the use of hornblende as an indicator mineral suggested that the presence of hornblende can only be used in a general manner as it too is not always truly indicative of the metamorphic grade. Because insufficient data is as yet available on the composition of the rocks from the thesis area, any attempt to utilize the hornblende present as an indicator mineral of specific metamorphic conditions seems unrealistic.

However, the appearance of garnets in some of the Janice Lake rocks is indicative of somewhat more specific metamorphic conditions (Fyfe, et. al., 1958). The presence of garnets shows that the upper regions of the greenschist conditions have been transgressed and that the conditions present in these rocks are either indicative of an intermediate grade (epidote-amphibolite facies) or of a higher grade (amphibolite facies) of regional metamorphism (Ramberg, 1952). Because of difficulties inherent in an accurate visual identification of any particular garnets (by the use of colour) it is impossible to state with any degree of certainty the

type of garnets present in the Janice Lake assemblage (Deer, Howie, and Zussman, 1966). This of course restricts the further use of this mineral as an indicator as to whether the conditions of metamorphism are intermediate grade or high grade.

Muscovite may occur over a rather large range of metamorphic conditions (Winkler, 1965) and its occurrence in trace amounts in the Janice Lake area does not seem significant in terms of the conditions of metamorphism which affected these rocks. Much the same can be said for the one occurrence of epidote in the thesis area. However, conditions of metamorphism that do favour the formation of this latter mineral appear to be more restricted than those favouring the formation of muscovite. Typically, the presence of epidote is taken to indicate intermediate conditions of metamorphism, particularly for the conditions usually associated with the transition area from the greenschist facies of regional metamorphism to the amphibolite facies (Barth, 1962). In the case of the Janice Lake area, the restricted occurrence of epidote in a peculiar metamorphic rock (meta-volcanic ?) suggests that perhaps composition is the dominant factor (Williams, et. al., 1954).

The presence of abundant microcline in the Janice Lake area suggests one of two alternatives: (1) That this mineral is a true metamorphic indicator, or (2) That some metasomatic effects, particularly an enrichment in either Na or K, or in both has taken place. Two approaches suggest that the presence of the microcline is probably due principally to metasomatic enrichment by K (and Na ?). The first of these approaches considers some of the textural aspects present in the Janice Lake rocks. In particular, the manner of occurrence of the microcline as large, fresh, unaltered porphyroblasts in many of the rock types. This textural feature may suggest an enrichment by alkalis (Williams, et. al., 1954), and when it is considered

in conjunction with the conspicuous absence of muscovite in the same rocks it would further tend to confirm the enrichment hypothesis (Winkler, 1965).

The second approach is a rather indirect one and makes use of the fact that Money (1967) has shown that definite metasomatic enrichment by alkalis has taken place in the Needle Falls area of the Wollaston Lake belt. Textural implications suggested by the manner of occurrence of some of the microcline in the Janice Lake area suggests that metasomatic enrichment has taken place. When these suggestions are considered in the light of Money's (1967) findings, it seems reasonable to postulate that enrichment by alkalis has indeed taken place to some extent in the rocks of the thesis area.

The occurrence of staurolite in the thesis area and the use of this indicator mineral by many workers (Harker, 1939), (Ramberg, 1952), (Fyfe, Turner and Verhoogen, 1958), (Miyashiro, 1961), (Barth, 1962) and (Winkler, 1965) suggests that this mineral may be indicative of the metamorphic grade for the Janice Lake area. Most workers agree that staurolite can only form in a very particular chemical environment rich in Al_2O_3 while somewhat impoverished in K_2O . FeO usually predominates over MgO (Barth, 1962, Winkler, 1965). However, there does seem to be some disagreement among some of these workers on the relationship between staurolite and the conditions of formation for this mineral. Winkler (1965) suggests that the presence of staurolite, given the proper chemical environment, indicates metamorphic conditions corresponding to the almandine amphibolite facies. Miyashiro (1961), is in agreement with this belief and feels that the presence of staurolite is indicative of the lower amphibolite facies of the kyanite-sillimanite

facies series. However, Barth (1962) includes staurolite, when in conjunction with sodic plagioclase, as a typical indicator of the epidote-amphibolite facies that lies at the threshold of the amphibolite facies of regional metamorphism.

The definition for the boundary between the greenschist facies and the almandine amphibolite facies is suggested by Fyfe, et. al. (1958) to lie at the change in the composition of plagioclase from less than or equal to $An_{7\%}$ (greenschist facies) to an anorthite content greater than or equal to 15% (almandine amphibolite facies). Further more, it is possible to make some generalizations that suggest that an increase in anorthite content of the plagioclase feldspars is in a general manner related to an increase in the metamorphic conditions (Ramberg, 1952. p. 147). The presence of sodic oligoclase with anorthite contents ranging between An_{15} to An_{20} (extinction angles vary from 3° to 8° , values taken from Kerr, 1959, p. 258) suggests that the rocks of the thesis area belong to the first subfacies of the almandine amphibolite facies of regional metamorphism as proposed by Fyfe, et. al. (1958). However, in their original proposal Fyfe et. al. (1958) did not make any formal allowances for the classification of metamorphic rocks with grades intermediate between those of the greenschist facies and those of the almandine-amphibolite facies. Because such an intermediate field of metamorphic conditions is however warranted, Barth (1962), proposed that the epidote-amphibolite facies occupy this position. Amphibolites with epidote and oligoclase as well as staurolite schists that contain sodic plagioclase are typical of this facies (Ibid. p. 311). Other workers, notably among them Winkler (1965) consider the presence of staurolite to be a decisive indicator for metamorphic conditions only associated with the almandine amphibolite facies of regional metamorphism (p. 87). Most likely

such rocks (containing staurolite) would belong to the staurolite–almandine subfacies of the almandine–amphibolite facies.

Conclusion

A study of indicator minerals present in the metamorphic rocks of the Janice Lake area suggests that the conditions of formation associated with these minerals are indicative of intermediate grade regional metamorphism. The presence of staurolite in some of these rocks furthermore suggests that these rocks may belong to either the kyanite–sillimanite facies series or to the low–pressure intermediate facies series of regional metamorphism.

The coexistence of staurolite and sodic plagioclase in the same rock implies that the rocks of the thesis area belong either to the epidote–amphibolite facies or to the staurolite–almandine subfacies of the almandine amphibolite facies. No conclusive evidence is presented to support either classification. However, in terms of a more recent classification of metamorphic conditions (Turner, 1968) it seems probable that the rocks of the thesis area belong to the somewhat ill defined field of the greenschist–amphibolite transition facies of regional metamorphism.

IV. DESCRIPTION OF THE MINERALIZATION

Introduction

Most of the base metal mineralization encountered along the Wollaston Lake belt is characterized by two distinct features; (1) the extremely fine grained and disseminated nature of the copper, lead, and zinc bearing minerals, and (2) the marked paucity of weathering effects in hand specimen. These features have contributed towards the difficulties which make normal prospecting procedures in this area somewhat cursory. Initial reconnaissance airborne geophysical surveys will not register anomalies over such areas as the Janice Lake region, principally because of the erratic grade and finely disseminated nature of the economic minerals. Soil geochemistry will show highly unreliable results, either because of thick glacial deposits or because of large swamps which characterize most of the belt. Consequently only two prospecting techniques have proven to be reliable in finding new occurrences of a similar type of mineralization as found in the thesis area. These techniques are, "boulder tracing" and a regional geochemical outcrop-sampling program. In 1966, on the basis of such a "rock-chip" regional geochemical program, mineralization was discovered in the Janice Lake area. To date two occurrences of a very similar nature have been found in this area, these are referred to as the Janice Lake and Kaz Lake occurrences respectively (see Fig. 2).

The purpose of this chapter is to present a description of the manner and occurrence of the mineralization associated with these two areas. Implications suggested by the investigation of the minerals present in these two occurrences will be deferred to section V of this thesis.

The Kaz Lake Occurrence

The Kaz mineral occurrence lies on the southwestern shore of Kaz Lake (Fig. 2). Outcrops in this area are relatively scarce and for some time it was believed that this occurrence was in fact a very large boulder. However, a more detailed investigation, consisting of stripping, blasting and drilling, revealed that this occurrence is most likely an outcrop (Plate I, No. 3). The mineralization occurs in a metaconglomeratic horizon of the massive hornblende-biotite gneiss of map unit A. This horizon is characterized by the presence of numerous pebbles, together with cobbles and a few boulders; most of which show some differential weathering relief within the matrix and are hence easy to recognize. No pegmatites occur on this "showing". The mineralization of this occurrence is by no means uniform throughout this horizon, but is concentrated in two irregular shaped sectors which together total up to an approximate area ten feet by ten feet. These mineralized portions were outlined by the use of a detailed geochemical survey as it is rarely possible to detect visually any of the mineralization in outcrop. Definite identification in hand specimen is also hampered by the high content of iron oxides and hydroxides present in all these rocks. Grab assays from this occurrence show the following results:

	%Cu	Ni(ppm)	ZN(ppm)	Pb	Ag oz/ton
sample 1	0.48	18	48	300ppm	0.2

Each large sample was broken into fragments, crushed to -10 mesh, and split into 100 gm aliquots before grinding. Two aliquots from two samples were analyzed separately to check for homogeneity of the crushed product. No significant differences were found in either case. All analyses were performed by the Geology Division, Saskatchewan Research Council. Values from private company report "Field Investigations, The Janice Lake Showing, 74-A-15 Saskatchewan," 1966, M. W. Pyke.

	%Cu	Ni(ppm)	Zn(ppm)	Pb	Ag oz/ton
sample 2	0.01	17	71	n/a	0.2
sample 3	0.44	29	78	n/a	0.1
sample 4	0.43	19	55	n/a	0.2
sample 5	0.40	20	60	300ppm	0.3
sample 6	0.79	9	130(?)	1.9%	1.0
sample 7	0.57	5	98	2.3%	0.5

Some malachite staining along fractures was also seen.

The Janice Lake Occurrence

The Janice Lake occurrence lies on the northwestern shore of Janice Lake (see Fig. 2). The mineralization associated with this occurrence is present both in the matrix of the metaconglomeratic horizons and in the associated massive hornblende biotite gneiss. The mineralization encountered in the Janice Lake occurrence tends to be distributed in irregularly shaped areas (Fig. 8). These mineralized portions were initially outlined by detailed geochemical sampling across most of the outcrops present in this region. Because of the numerous pegmatites associated with the Janice Lake occurrence, it is also possible at times to indirectly locate the more mineralized portions. A detailed study of the pegmatite contacts will sometimes reveal the presence of bornite and chalcopyrite blebs adjacent to these contacts (Plate IV, No. 2). These blebs seem to occur only in those pegmatites which cut the mineralized parts of the hornblende-biotite rock. No concentration of the mineralization in veinlets, stringers, or larger blebs could be found, divorced from a pegmatite in any of the host rock. In fact, blasting on both the Janice and Kaz occurrences has revealed that the mineralization consists of minute, finely disseminated particles which tend to be concentrated in irregularly-shaped regions of the metaconglomeratic hornblende biotite gneiss. Some secondary malachite stains

along fracture surfaces was also noted.

Results from two inclined drill holes under trench No. 1 of the Janice Lake occurrence returned the following results:¹

- (1) Three zones of copper mineralization occur over a maximum true width of 17.7'.
- (2) Two of the zones, having true widths of 1.4' and 3.5' respectively, contain native copper and chalcocite mineralization, estimated to constitute from less than 1% to 3% of the core by volume.
- (3) A third zone, having a true width of 2.1', contains native copper mineralization, estimated to constitute approximately 1% of the core by volume.

Assay results returned from one of these drill holes showed the following copper values over five foot widths:²

from 0' to 5'	less than 0.1% Cu
5' to 10'	0.22% Cu
10' to 15'	0.26% Cu
15' to 20'	0.14% Cu
20' to 25'	0.1% Cu

Ore Mineralogy

Examination of polished sections from both occurrences reveals that the macroscopically recognizable mineralization consists of fine grained native copper and chalcocite. Bornite and covellite occur associated with the chalcocite. Most

¹ M. W. Pyke private company report "Field Investigations, The Janice Lake Showing, 74-A-15 Saskatchewan," 1966.

² Ibid.

of the malachite present occurs as thin films along fracture surfaces or as coatings around chalcocite grains. Of the twelve polished sections prepared, only seven proved to be useful in the identification of the mineralization. The other five sections only contained magnetite and ilmenite, mistakenly identified in hand specimen as chalcocite.

The native copper of both "showings" occurs as irregular shaped masses. Under the ore microscope this mineral exhibits the typical tarnished red-brown colour associated with a faint "false" anisotropic effect (Schouten, 1962). Most of the surfaces examined show numerous scratches as well as being surrounded by darker rims of apparently more intense tarnished copper. Approximate grain size estimates vary from .001mm to .01mm. Reflectivity measurements were unsuccessful because of the small size of the individual particles present. Examination of thin-sections from the more mineralized portions of the host rock revealed that the majority of the native copper apparently occurs within the feldspathic fraction of this rock, particularly along feldspar grain interfaces. The most favourable loci for the highest concentration of the native copper appears to be at grain intersections within these feldspathic fractions.

Further analysis of the polished sections shows that the chalcocite occurs as variably shaped grains characterized by irregular outlines. Some of the grains are surrounded by visible rims of malachite. Approximate grain sizes vary from .01mm to .02mm. Most of the grains examined show a faint variability of birefractance colours ranging from bluish white to somewhat pinkish. All the grains examined were weakly anisotropic with very indistinct polarization colours. An

X-ray diffraction analysis of one grain of chalcocite by Dr. J. R. Smith¹ showed that this grain consists of fine lamellar intergrowths of chalcocite and bornite coated by a faint rim of covellite. The faint pinkish bireflectance colour noted in other chalcocite grains examined suggests that these grains may also consist of similar such intergrowths (Schouten, 1962). Most of the chalcocite grains examined were surrounded by a faint visible rim of malachite.

Examinations of thin sections from the more mineralized portions of the host rock suggest that the occurrence of chalcocite is also restricted to the more feldspathic fractions of the hornblende-biotite rock of map unit A. No other relationships between the chalcocite and native copper were noted.

Geochemical Survey over the Janice Lake Occurrence

In order to more fully understand the manner of occurrence of the copper mineralization associated with the thesis area, a detailed rock geochemical sampling program was undertaken by Great Plains Development Ltd. on the Janice Lake occurrence. Samples, taken by the use of a small plugger drill, were collected from an approximate depth of one foot into the bedrock. These samples came from twenty-five foot intervals along picket lines spaced fifty feet apart. All samples taken were analyzed² for copper, lead, zinc, uranium, and molybdenum. The degree of error to be expected from this type of program ranges from 5-10ppm for the various elements (M. W. Pyke, personal communication).

With reference to Fig. 7 it may be seen that most of the Janice Lake

¹Geology Division, Saskatchewan Research Council. Private Company report.

²Ibid.

occurrence is characterized by quite high lead and zinc values. The average values along the outcrops for both lead and zinc vary somewhat between 65ppm to 75ppm with ranges of 53ppm to 191ppm Pb and 5ppm to 264ppm Zn. To date, no mineralization carrying these metals has been identified from this occurrence. The average value for copper along the outcrops lies between 10ppm and 20ppm with a range from 0ppm to 3500 ppm Cu. With reference to Fig. 8 it may be seen that anomalous regions defined by the 150ppm Cu contour outline are essentially those areas that have been trenched and drilled. From these areas came some of the previously discussed samples. The overall average content of uranium along most of the outcrops varies somewhat between 0ppm to 2ppm with a range of values from 0ppm to 110ppm U. For molybdenum, the average outcrop value is 5ppm with a range of values from 0ppm to 96ppm Mo. To date, no mineralization associated with these latter two elements has been identified within the Janice Lake occurrence.

With reference to Fig. 7, a tentative correlation is suggested between those areas anomalously high in lead and those areas anomalously high in zinc. However, no definite pattern seems to be implied by the areal distribution of these regions.

A tentative correlation may be suggested between those areas containing anomalous uranium values and those areas defined as metaconglomerates. With reference to Fig. 8, the anomalous regions of uranium values seem to lie in close juxtaposition to such metaconglomeratic horizons.

Implications suggested by the manner and occurrence of the mineralization found in the thesis area will be discussed in section V.

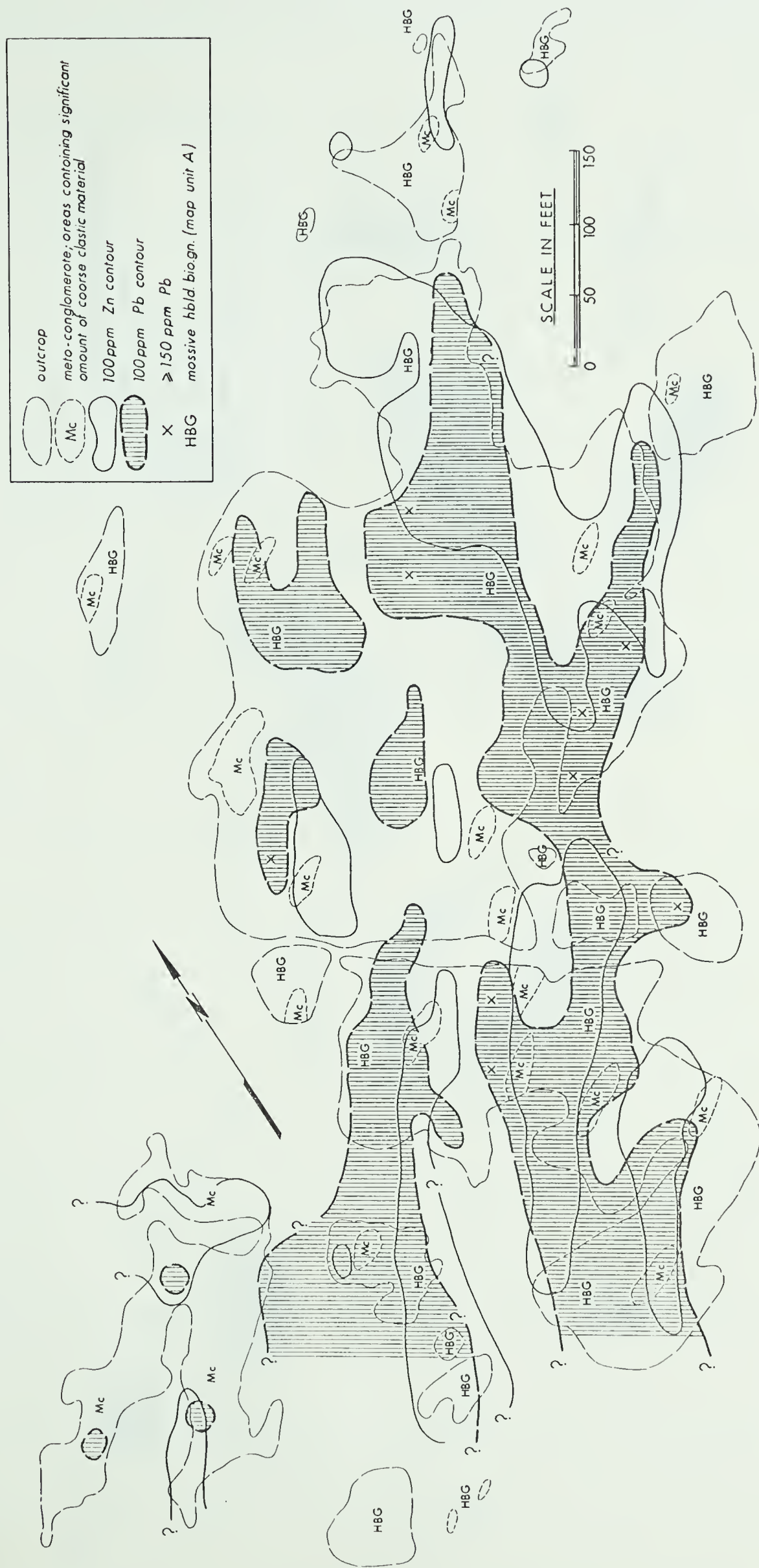


FIG.7. DISTRIBUTION OF LEAD AND ZINC (ppm) IN BEDROCK OF THE JANICE LAKE OCCURRENCE



FIG. 8. DISTRIBUTION OF COPPER, MOLYBDENUM AND URANIUM (ppm) IN BEDROCK OF THE JANICE LAKE OCCURRENCE

V. ORIGIN OF THE METAMORPHIC ROCKS AND MINERALIZATION

The Metamorphic Rocks

Introduction

The purpose of this section is to consider the origin of the metamorphic rocks previously described (see section II) and to deduce as much as possible about their depositional environment. Initial considerations on the genesis of these rocks will involve the use of observable field and petrographic criteria. An attempt will then be made to augment these preliminary considerations with the results obtained from several selected chemical analyses of the various principle rock types found within the thesis area.

Field Criteria

No conclusive field evidence can be presented to either refute or substantiate the assumption that most of the rocks found in the vicinity of Janice Lake are paragneisses. However, on the basis of several pertinent chemical analyses (see chemical analyses) and on the basis of other related studies (Money, 1967, Chadwick, 1967) it seems probable that most of the rocks of the thesis area were originally sedimentary. Therefore, any further considerations of the genesis of the metamorphic rocks found in the thesis area will be based upon the assumption that most of the rocks were originally sedimentary. Some of the features inherent in the Janice Lake lithologies will now be discussed in order to further evaluate the origin and depositional environment of these rocks.

One of the most apparent characteristics of the rocks of the thesis area is their extremely variable nature. Typically each map unit will consist of several

related lithologies which grade into each other over relatively short distances (see section II). This apparent inhomogeneity is also expressed on a much smaller scale, as suggested by the heterogeneous mixture of two "fractions" which together comprise much of the massive hornblende biotite gneiss of map unit A (see Fig. 4). It seems probable that this internal characteristic of the hornblende biotite gneiss is inherited from its sedimentary origin (Turner, 1968). The variation of the nature of the rocks over small distances has been interpreted by Chadwick (1967, p.12) as being typical of sedimentary environments characterized by rapid deposition. Pettijohn (1957), in a discussion of the influence of tectonics on the maturity of clastic sediments, relates the rate of deposition to the geometry and textures of each sedimentary unit. He goes on to say that depositional environments characterized by rapid erosion will yield immature sediments. Such sediments are typically characterized by a high degree of internal heterogeneity (Krumbein and Sloss, 1963). These heterogeneous sediments have collectively been called wackes by Williams, et. al. (1954, p. 280).

The presence of several metaconglomeratic horizons in the vicinity of Janice Lake may be used in further considerations on the origin and depositional environment of these rocks. With reference to Table III, it may be seen that the predominant clastic debris present in these rocks consists of quartz pebbles and cobbles. Some larger "granitic" boulders also occur within these horizons (Plate II, No. 2). Pettijohn (1957, p. 254), in a discussion of the classification of conglomerates, considers texture, maturity, and source terrain to be the most useful parameters in differentiating the various types of coarse clastic sediments. He goes on to say

that the presence of predominantly quartz pebbles and cobbles in a well sorted conglomeratic bed is indicative of a low relief source terrain and high degree of maturity for the conglomerate (p.253). However, the persistence of "granitic" boulders in a conglomerate characterized by a high degree of internal heterogeneity implies that the metaconglomerates of the thesis area are more likely a product of rapid erosion from a source terrain with high relief (Pettijohn, 1957, p.253).

The type of clastic debris present in a conglomerate may also be used as an indicator of the source terrain (Williams et. al., 1954, p. 171). Usually the presence of numerous quartz pebbles and cobbles in a coarse clastic sediment (such as a conglomerate) indicates an igneous and/or metamorphic source terrain for this debris (Krumbein and Sloss, 1963, p. 163). On the basis of this consideration, the modal analyses (see section II) of two large "granitic" boulders present in the Janice Lake metaconglomerate suggest that at least some of the source terrain could have originally consisted of igneous rocks of granodioritic and/or quartz monzonitic composition. Money (1968), in a discussion of the source terrain for the meta-arkose of the Needle Falls area, was able to demonstrate that these rocks were indeed derived at least in part from an older Archean (app. 2220m.y. to 2700m.y.) "granitic" complex. This source terrain is believed to have had a quartz-monzonitic composition (p.149).

Pettijohn (1957), in a discussion of the maturity of sediments, considers a high amount of quartz (greater than 90%) present in such rocks to be indicative of a high degree of maturity. Conversely, a high content of feldspars and other material present in sediments may be indicative of a relatively immature rock

(Williams et. al., 1954). The presence of large polycrystalline aggregates of quartz in many of the rocks found in the thesis area suggests that at least the majority of this material recrystallized from original sedimentary quartz (Turner, 1968, p. 1). With reference to Fig. 3, it may be seen that all the metamorphic rocks present in the thesis area are characterized by a relatively low quartz content (generally less than 50%) and by a relatively high content of other constituents. Sedimentary rocks characterized by such a low quartz content and by a relatively high feldspar content have been termed arkosic wackes or arkosic arenites by Williams, et. al (1954, p. 292). Of these two types, the arkosic wackes are typically deposited "at a comparatively rapid rate without appreciable selection or reworking by currents after deposition," (Williams, et. al., 1954, p. 289). Therefore, on the basis of previously considered field criteria, the original sedimentary rocks deposited in the Janice Lake area could have been in part of the arkosic wacke type.

Chemical Criteria

With reference to Fig. 2 and the geological map of the Janice Lake area (in pocket), it may be seen that the two most prominent lithological units present consist of the previously discussed hornblende biotite gneiss (map unit A) and a biotite gneiss (map unit B). A chemical analysis of one specimen from each of these units and selected standard rocks is given in Tables V and VI. Presented in Tables VII and VIII are chemical analyses of a meta-arkose and meta-volcanic (?) also from the thesis area and several selected standard analyses of similar rocks.

Because evidence to the contrary is lacking, a first assumption is made to the effect that the metamorphic reactions affecting the rocks of the thesis area

operated essentially in an isochemical manner. Petrographic evidence (section II) and a study of the metamorphic indicator minerals (section III) have suggested that some metasomatic enrichment by alkalis has taken place in the rocks of the thesis area. A general comparison of the chemical analyses of the rocks from the Janice Lake area and of standard analyses of similar rocks shows that the rocks of the thesis area are essentially higher in K_2O and Na_2O than most of the standard rocks. Particularly evident is the apparently high alkali content of the biotite gneiss from the Janice Lake area (Table VI). Therefore, any consideration that assumes the rocks of the thesis area behaved in an isochemical manner must be somewhat modified by the available evidence suggesting that some enrichment by alkalis has taken place.

Field evidence has suggested that the source terrain for most of the rocks found in the thesis area was igneous and of a general "granitic" composition. A comparison of chemical analyses presented in Tables V and VI substantiates this suggestion. That is, the chemical analyses of the hornblende biotite gneiss and of the biotite gneiss suggest an igneous heritage exemplified by the similarity of these analyses and standard analyses of a quartz monzonite, calc-alkali granite, and arkose (presumably derived from a "granitic" source terrain). Furthermore, in the light of other findings (Money, 1967), it seems probable that the igneous rocks of the source terrain had a quartz monzonitic or calc-alkali granitic composition.

Preliminary field investigations have suggested that the original sedimentary rocks deposited in the thesis area were a product of rather rapid erosion and accumulation. The comparative chemical analyses presented in Tables V and VI suggest that the weathering products of the original igneous source terrain, have a

Table V: Chemical Analyses of a Massive Hornblende-Biotite
Gneiss and of Several Selected Standard Rocks

	Hornblende Biotite Gneiss	Average Quartz Monzonite ¹	Composite Sample of Mississippi Delta Sediment ²	Average Graywacke ³
SiO ₂	69.81	69.51	69.96	68.1
TiO ₂	0.41	0.56	0.59	0.7
Al ₂ O ₃	13.20	14.63	10.52	15.4
Fe ₂ O ₃	1.44	1.22	-	1.4
FeO	1.91	2.27	-	3.4
(total iron)	(3.55)	-	3.47	-
MnO	0.07	0.06	0.06	0.2
MgO	1.26	0.99	1.41	1.8
CaO	1.45	2.45	2.17	2.3
Na ₂ O	3.20	3.35	1.51	2.6
K ₂ O	5.00	4.58	2.30	2.2
P ₂ O ₅	0.12	0.20	-	0.2
Cu	0.59	-	-	-
L.O.I.	1.25	-	-	-
Total	99.71	-	-	-

1 Nockolds (1954), p. 1014

2 Pettijohn (1957), p. 344

3 Ibid., p. 307.

Table 1. Chemical composition of the rocks from the study area.

Sample	SiO ₂	TiO ₂	Al ₂ O ₃	FeO	MnO	MgO	CaO	Na ₂ O	K ₂ O	Total
Hornblende	52.8	1.2	15.20	14.4	0.1	10.2	0.1	0.1	0.1	80.91
Biotite Gneiss	52.8	1.2	15.20	14.4	0.1	10.2	0.1	0.1	0.1	80.91
Average Gneiss	52.8	1.2	15.20	14.4	0.1	10.2	0.1	0.1	0.1	80.91
Monzonite	52.8	1.2	15.20	14.4	0.1	10.2	0.1	0.1	0.1	80.91
Composite sample of Mississippi Delta Sediment	52.8	1.2	15.20	14.4	0.1	10.2	0.1	0.1	0.1	80.91
Average Graywacke	52.8	1.2	15.20	14.4	0.1	10.2	0.1	0.1	0.1	80.91

Table VI: Chemical Analyses of a Biotite Gneiss and of Several Selected Standard Rocks

	Biotite Gneiss	Subgraywacke ¹		Average Arkose ²	Average Alkali Granite ³
SiO ₂	74.43	74.43	76.84	76.37	72.08
TiO ₂	0.33	0.83	-	0.41	0.37
Al ₂ O ₃	12.46	11.32	11.76	10.63	13.86
Fe ₂ O ₃	1.81	0.81	0.55	2.12	0.86
FeO	0.26	3.88	2.88	1.22	1.67
MnO	0.01	0.40	tr.	0.25	0.06
MgO	0.56	1.30	1.39	0.23	0.52
CaO	0.02	1.17	0.70	1.30	1.33
Na ₂ O	2.22	1.63	2.57	1.84	3.08
K ₂ O	7.40	1.74	1.62	4.99	5.46
P ₂ O ₅	0.11	0.18	-	0.21	0.18
L.O.I.	0.48	-	-	0.83	0.53
Total	100.09				

1 Pettijohn (1957), p. 319.

2 Ibid., p. 324.

3 Nockolds (1954). p. 1012.

Table VII: Chemical Analyses of a Meta-Arkose
and of Several Selected Standard Rocks

	Juno Lake Meta-Arkose	Average Arkose ¹	Average Calc- Alkali Granite ²
SiO ₂	72.99	76.37	72.08
TiO ₂	0.36	0.41	0.37
Al ₂ O ₃	12.51	10.63	13.86
Fe ₂ O ₃	2.49	2.12	0.86
FeO	0.51	1.22	1.67
MnO	0.06	0.25	0.06
MgO	1.04	0.23	0.52
CaO	0.87	1.30	1.33
Na ₂ O	3.10	1.84	3.08
K ₂ O	4.40	4.99	5.46
P ₂ O ₅	0.13	0.21	0.18
L.O.I.	1.11	0.83	0.53
Total	99.57	100.94	

1 Pettijohn (1957), p. 324.

2 Nockolds (1954), p. 1012.

Table VIII: Chemical Analyses of a Metavolcanic
and of a Standard Rock

	Meta-Volcanic	Average Rhyodacite ¹
SiO ₂	66.35	66.27
TiO ₂	0.59	0.66
Al ₂ O ₃	14.84	15.39
Fe ₂ O ₃	3.63	2.14
FeO	1.09	2.23
MnO	0.04	0.07
MgO	1.69	1.57
CaO	1.51	3.68
Na ₂ O	3.70	4.13
K ₂ O	4.90	3.01
P ₂ O ₅	0.23	0.17
L.O.I.	1.06	0.69
Total	99.63	

¹ Nockolds (1954), p. 1014.

gross chemical composition similar to that of a standard arkose, subgraywacke or graywacke. All these rock types are typically accumulated in an environment characterized by rapid deposition (Pettijohn, 1957; Krumbein and Sloss, 1963). Very little direct evidence can be presented that will substantiate the choice of any one of these distinct sedimentary rocks (in terms of tectonic environment) as the likely correlative to the original sedimentary rocks deposited in the thesis area.

However, on the basis of some "normal" consanguineous associations of various sedimentary rocks presented by Pettijohn (1957, p. 610) it seems probable that the rocks of the Janice Lake area may belong to the subgraywacke or arkosic suite. Supporting field criteria for this assumption are: (1) The manner and occurrence of the mineralization found in these rocks (see next part), and (2) The finely laminated character of the meta-arkose (Plate II, No. 1) may be an inherent characteristic of the rock. Such regularity and internal stratification of sediments is not characteristic of graywackes, one of the major constituents of the graywacke suite (Pettijohn, 1957, p. 302). Furthermore, arkoses as defined by Pettijohn (1957) reflect a deposition in a media capable of some effective separation of such material as clay, silt, and sand. This regularity and sorting action is not usually associated with a graywacke-type depositional environment (Krumbein and Sloss, 1963). However, Williams et. al. (1954) point out that arkose and graywacke can be neither strictly compared nor distinctly contrasted as they are defined by somewhat different criteria (p. 295).

Conclusion

According to Goodwin (1968, p. 10) lower Proterozoic sediments found within the central part of the Churchill (structural) province are "for the most part of miogeosynclinal facies . . . representative of intracratonic rather than marginal basins." Money (1968, p. 1501), in a summary of the depositional environment of the various rock types found along the Wollaston Lake belt, considers that most of these rocks belong to a miogeosynclinal assemblage (Daly Lake Group) of pelites, arkose, and graywacke associated with a minor eugeosynclinal assemblage of graywacke, intermediate volcanics, and arkose (Sandfly Lake Group) and a stable shelf assemblage represented by the Meyers Lake Group.

Chemical analyses of the rocks found in the Janice Lake area and a suggested correlation of these rocks with other similar lithologies found along the Wollaston Lake belt (Table II), suggest that the rocks of the thesis area may provide a "link" between members of the Daly Lake Group and Sandfly Lake Group respectively.

Field evidence, supported by select chemical analyses, has suggested that the rocks found in the vicinity of Janice Lake may belong to either the arkosic suite or subgraywacke suite as proposed by Pettijohn (1957). One alternative of a depositional environment suggested for the rock types belonging to these two suites is in marginal areas, close to the craton (Pettijohn, 1957). A tentative conclusion may then be drawn that suggests that the sedimentary rocks deposited in the Janice Lake area are the products of paralic sedimentation and that these rocks may be in part representative of the "nearshore" facies of the Daly Lake and/or Sandfly Lake Group (see Table V, Composite Sample of the Mississippi Delta Sediment).

Origin of the Mineralization

The purpose of this section is to consider the possible genesis of the mineralization encountered in the metamorphic rocks of the Janice Lake area. The preliminary suggestions made in this section must await results of isotopic studies of both lead and sulphur (in preparation) of some of the mineralization found along the Wollaston Lake belt before any final conclusions can be made.

Horn and Adams (1966) have presented a model geochemical balance of most of the major elements found in the earth's crust in an attempt to define elemental abundances and their relation to a sedimentary-oceanic model of the earth's crust. Because of the apparent success of this computed model, all elemental abundance data used in this thesis have been taken from this study. A comparison of the amount of Cu, Pb, Zn, Mo, and U found in the rocks around Janice Lake (see section IV) with the maximum and minimum amounts for the presumed sedimentary equivalents to these rocks (Horn and Adams, 1966, Appendix C, p.293) suggests that the abundance of these elements in the Janice Lake area is anomalously high. The base metal mineralization present in the thesis area has been previously described in section IV. Copper occurs principally in chalcocite and as the native metal, also present are minor amounts of bornite, covellite, and malachite. No ore minerals carrying Pb, Zn, Mo, or U have yet been identified in the thesis area, but the higher concentration of these metals might be related to the occurrence of the copper bearing minerals that have been identified. A review of pertinent genetic classifications of ore deposits suggest that the mineralization found in the Janice Lake area may be either of epigenetic telethermal origin or of syngenetic sedimentary origin (Park and MacDiarmid, 1964). These alternatives will now be

evaluated.

The occurrence of copper, uranium, molybdenum, lead, and zinc in coarse grained clastics ("red-bed" type deposits) may be attributed to a hydrothermal origin (Hosteler and Garrels, 1962; Jensen, 1958). Well known examples are the deposits found in the Colorado Plateau and adjacent areas (Fisher, 1950). Here the ores are associated principally with beds of sandstones, siltstones, conglomerates, and limestones (Park and MacDiarmid, 1964, p. 332). The presence of cracked hydrocarbons (temperature range for this 100°C to 350°) and a typical hydrothermal suite of numerous minerals such as galena, sphalerite, chalcopyrite, and alunite suggest an epigenetic origin for these occurrences. Graton (1933) proposed the term telethermal for such deposits. Some workers, notably among them Hosteler and Garrels (1962), have shown that the manner and occurrence of the mineralization encountered on the Colorado Plateau is related to the distribution of reactive sediments such as limestones. When mineralizers moving through the rocks encountered these limestones, precipitation of metals took place. This mechanism may be used to explain the characteristic occurrence of sandstone ore-horizons beneath limestones (Fisher, 1950). The apparent absence in the thesis area of any nearby reactive rocks such as calcareous metasediments (which could have facilitated the precipitation of metals from charged mineralizers) may suggest a different origin for the mineralization of the Janice Lake area than for the deposits of the Colorado Plateau. Moreover, there is as yet no evidence in the thesis area of the typical suite of other minerals that are commonly characteristic of hydrothermal deposits.

Alternately, the association of copper and anomalously high values of

uranium in the metasediments of the thesis area may suggest a mode of origin for the mineralization of the Janice Lake area similar to that of occurrences such as those of the Witwatersrand deposits of South Africa (Pelletier, 1964), the Zambian-Congolese copper deposits also of South Africa (Pelletier, 1964), the cupriferous sandstones of Eastern Siberia (Bogdanov, 1962), and possibly the Kupferschiefer-Marl Slate deposits of Europe (Dunham, 1964). All of these deposits are believed to have been originally formed in a paralic environment. Some noteworthy characteristics of these deposits are: (1) The presence of significant quantities of metalliferous minerals in conglomeratic horizons, (2) The widespread occurrences of such hypogene minerals as chalcocite, and (3) The fine grained nature of the ore minerals (particularly in the Kupferschiefer).

Because the initial syngenetic sedimentary nature of the South African and European deposits has been modified by varying degrees of deformation and supergene enrichment, no direct analogies can be made between these deposits and the mineralization found in the Janice Lake area. However, the manner and occurrence of the cupriferous Precambrian sandstones of Eastern Siberia offers a striking parallelism (Bogdanov, 1962).

In Eastern Siberia, sandstones and argillaceous lithologies occur within a series of small linear troughs which together comprise a northwest trending belt some 100 km long. The stratigraphic succession found along this belt suggests a shallow water deltaic depositional environment. The principal mineralization is similar to that of the Janice Lake area in that it consists of primary chalcocite associated with chalcopyrite, pyrite, bornite, and pyrrhotite. The Russian geologists who have studied the Siberian deposits are convinced that most of the mineralization is of syngenetic origin (Bogdanov, 1962). Most of the rocks have

undergone regional metamorphism corresponding to the greenschist facies. However, some rocks of higher metamorphic grade have also been recorded in this belt.

Where metamorphic conditions exceeded those of the greenschist facies, it is possible to recognize a regeneration of copper sulphides which gave rise to the formation of secondary bornite and chalcopyrite. There is evidence of similar regeneration of sulphides within the Janice Lake area along the contacts of pegmatites (see section IV and Plate IV, No. 2). Thus in several respects the Siberian deposits resemble those of the thesis area.

At this time, no conclusive evidence can be presented from the present studies of the metallic mineralization encountered in the thesis area that would specifically prove either a syngenetic origin or an epigenetic (telethermal) origin. However, it appears most likely that the base metals in the Janice Lake area are syngenetic in origin, on the basis of the following considerations: (1) The absence of any immediate reactive rocks such as calcareous sediments which could have facilitated the precipitation of metals from mineralizers, (2) The association of the copper minerals and metaconglomeratic horizons, (3) The fine grained nature of the mineralization, (4) The documented evidence (Park and MacDiarmid, 1964) that chalcocite can form under near-surface conditions, particularly under those encountered in a paralic environment, (5) The presence of secondary rims of covellite surrounding most of the chalcocite grains which may imply that the chalcocite was an "original" constituent of the sediments and that subsequent metamorphic deformation resulted in the formation of the covellite rims, and (6) The striking parallelism between the mineral assemblage and mode of occurrence of the Janice Lake deposits and those of the cupriferous sediments of the Udokan region of Eastern

Siberia. The manner and occurrence of the native copper present in the rocks of the thesis area suggest that this metal had a supergene origin (see section IV).

Conclusion

Preliminary investigations of the base metal mineralization in the rocks of the Janice Lake area suggest that it may be of syngenetic sedimentary origin. This tentative conclusion is based upon comparisons with other similar deposits in the world.

VI. SUMMARY AND CONCLUSIONS

Regional studies of Precambrian crustal evolution, as exhibited by the Canadian Shield, suggest that the Wollaston Lake fold-belt system may represent the remnants of a linear intracratonic basin. Such basins are believed to be a typical geosynclinal configuration of Aphebian time (Goodwin, 1968). The widespread occurrence of metamorphosed pelites, arkoses, and graywackes found along this fold belt (Daly Lake Group) suggest a miogeosynclinal assemblage accumulated by rapid deposition on a sialic basement in close proximity to a source terrain characterized by a variety of granitic rocks (Money, 1968).

A correlation of the metamorphic rocks found in the Janice Lake area with other similar rocks found along the Wollaston Lake trend, suggest that the Janice Lake assemblages provide a possible "link" between members of the Daly Lake Group and Sandfly Lake Group.

Field evidence supported by chemical analyses of representative specimens from the thesis area suggest that these rocks originally consisted of arkose, subgraywacke, and acidic volcanic rocks (?). These rocks may represent a penecontemporaneous paralic facies of either the Daly Lake Group and/or Sandfly Lake Group.

A comparison of the type of ore mineralization and type of host rock found within the thesis area with other similar world-wide occurrences, suggests that some of this mineralization encountered in the vicinity of Janice Lake may be of syngenetic sedimentary origin.

The possible presence of syngenetic deposits, associated with the

rocks of the Wollaston Lake belt, would substantiate the suggestion (Pyke and Partridge, 1967) that this trend may represent a unique metallogenic province in the Canadian Shield.

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APPENDIX I METHODS USED

Part I: Petrographic Methods

Thin sections were cut from selected samples of each major rock type. An attempt was made to select representative specimens which incorporated most of the apparent varieties of these rock types. The descriptive terminology is taken from Moorhouse (1959), Williams et. al. (1954) and Kerr (1959). The plagioclase composition was determined on sections cut normal to (010) as described by Kerr (1959). A modified Michel-Levy method was also employed. After verification of the orientation of the section, only maximum extinction angles were measured for both the fast ray and the slow ray. Only the values obtained from the fast ray were recorded. Also recorded, whenever possible, was the optic sign, $2V$, and the apparent refractive index (relative to the mounting medium) of each plagioclase grain studied. At least 5 to 6 separate extinction angle measurements were made for each slide.

Point counting proceeded in two stages; in the first stage a minimum of 500 points per slide were counted. The results thus obtained were verified by the second stage of point counting (also 500 points per slide). The values obtained from these two stages were averaged, recorded, and plotted on ternary diagrams. By counting grains in two stages, the author felt that this would reduce the personal bias inherent in any point counting procedure (Griffiths, 1960).

Part II: Ore Microscopy

The samples were chosen from fresh blasted rocks from both the Janice and Kaz occurrences. Because of the nature of the ore mineralogy in these rocks,

all specimens were cut into numerous thin slabs. Each slab was examined under the microscope to determine if any mineralization was present. Then most of the samples were mounted in epoxy resin and polished on a MECAPOL polishing machine. However, of the twelve specimens prepared, only seven contained significant mineralization, the other five polished sections contained magnetite and ilmenite mistakenly identified in hand specimen as chalcocite. Several other specimens were also mounted in lucite and hand polished. The mineralization present in these latter specimens is the same as that found in the first seven. The terminology used is taken from Cameron (1961) and results obtained were corroborated with Schouten (1962) and with the "Card Index of Ore Photomicrographs" (Bildkartei Der Erz-mikroskopie, 1965).

Part III: Chemical Analyses

Because of time and facility limitations only four samples were submitted for chemical analysis. These samples are, a massive hornblende-biotite gneiss (R68-18), a biotite gneiss (R68-44B), a meta-arkose (Jun-3A) and a meta-volcanic(?) (R68-50). All analyses were performed by Mr. A. Stelmack.

The samples chosen were crushed and powdered by hand in order to avoid any contamination. After crushing, one quarter aliquot of the original sample was further reduced to an approximate 80 - 120 mesh size. All the grinding was performed using a quartz agate mortar. The final powdered sample was mixed to ensure complete homogenization and then one half of the original material was submitted for the chemical analysis.

The general procedure for these analyses is taken from Baadsgaard (1956)¹ and Lundell et. al. (1953). The samples were analyzed by wet chemical techniques and the results were obtained by either colorimetric comparison, gravimetric analysis, titrimetric analysis, or flame photometry. The expected degree of error, taken from Lundell et. al. (1953) is as follows: for constituents comprising greater than 30% of the rock the expected error ranges from 0.2% to 0.3%, for constituents comprising 10% to 30% of the rock 0.1% to 0.2%, and for constituents comprising 1% to 10% of the rock 0.05% to 0.1%.

¹"Rock and Mineral Analysis," H. Baadsgaard (1956), University of Alberta Laboratory Manual, unpublished.

Plate I

1. Subdued relief typical of most of the thesis area. Picture taken near the junction of Janice Lake and Wathaman River, looking north.
2. Janice "showing", trench No. 1, on western shore of Janice Lake.
3. Kaz "showing", trench No. 1, on southwestern shore of Kaz Lake.

1



2



3



PLATE I.

Plate II

1. Juno Lake Meta-Arkose (rock type of uncertain stratigraphic position). Distinct colour laminations seen on outcrops characteristic of this rock type.
2. Hornblende Biotite Gneiss (map unit A). Large "granitic" boulder found in a conglomeratic horizon characterized principally by an abundance of quartz pebbles and cobbles (see below). From Janice mineralization occurrence.
3. Hornblende Biotite Gneiss (map unit B). Typical conglomeratic horizon found in this rock type. Majority of the coarse clastic material present consists of deformed quartz pebbles and cobbles. From Janice mineralization occurrence, near trench No. 1.



PLATE II.

Plate III

1. Biotite Gneiss (map unit B). Faint colour banding sometimes associated with varieties of this rock type. Layering suggests original bedded nature of the rock (?). From outcrop north of Janice Lake.
2. Meta-Volcanic(?). Typical outcrop showing fine grained dark nature of the rock. Note the presence of discrete parallel quartz stringers. From southern portion of the map area.
3. Meta-Volcanic(?). This exposure shows the very thinly layered character of the rock suggesting a tuffaceous origin(?). From southern portion of the map area.

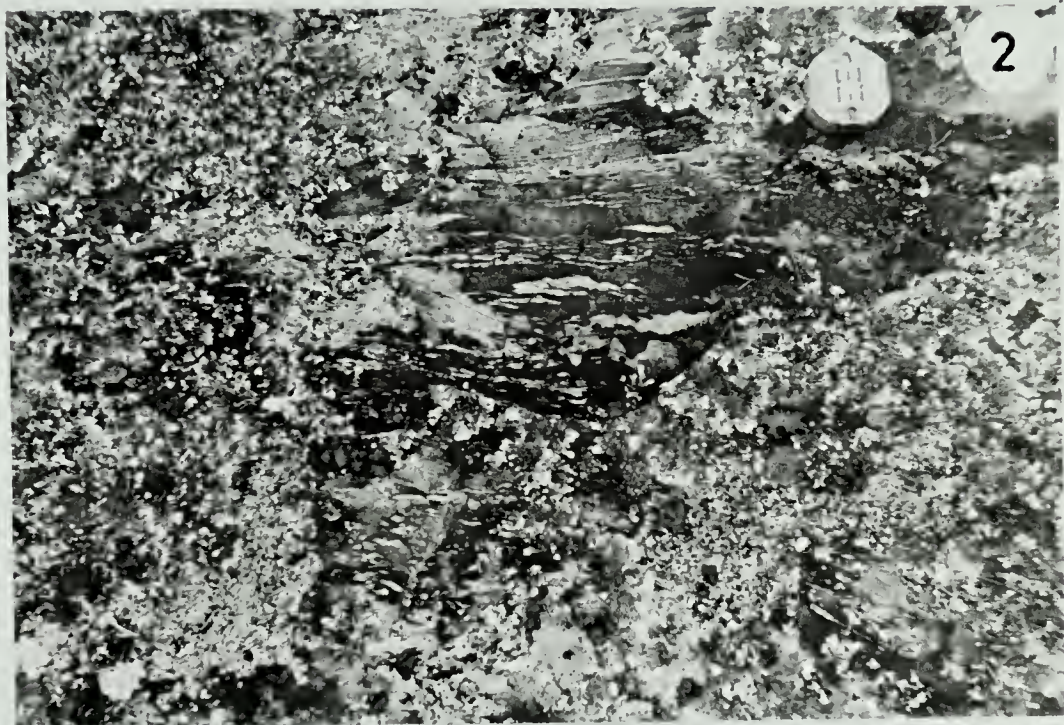
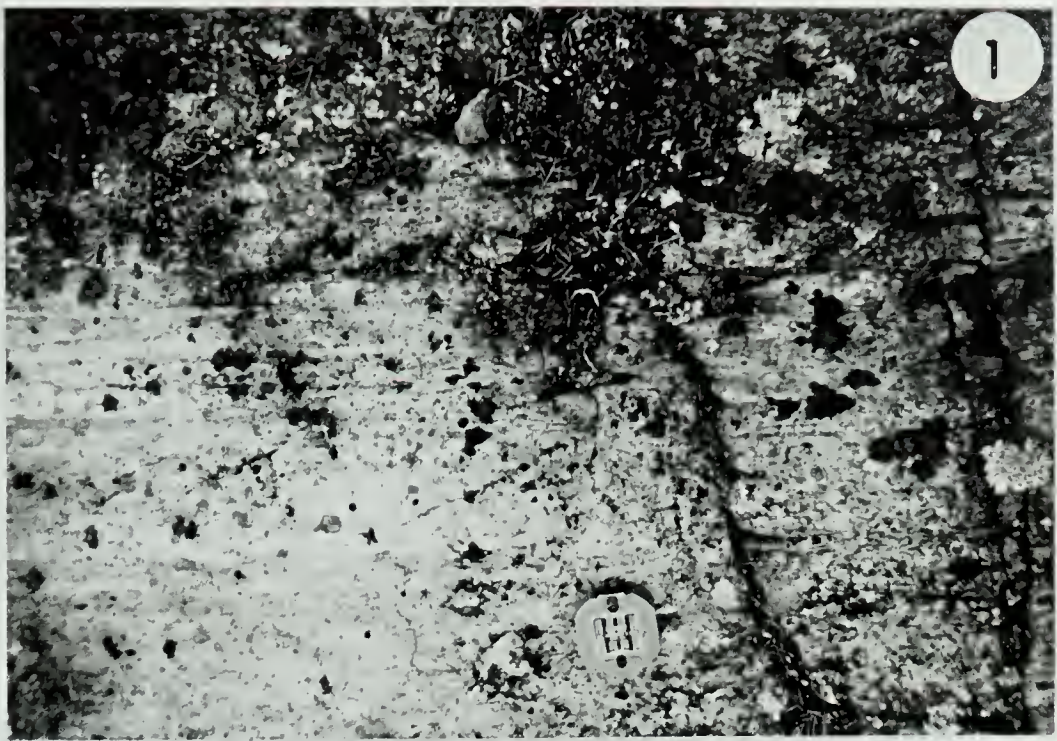


PLATE III.

Plate IV

1. Hornblende Biotite Gneiss (map unit A). Deformed porphroblasts found in the conglomeratic variety of this rock type. From Janice mineralization occurrence, trench No. 1.
2. Blebs of bornite (B) along pegmatite contact cutting the mineralized hornblende biotite gneiss. From Janice mineralization occurrence.
3. Hornblende Biotite Gneiss (map unit A). Native copper (Cu) finely disseminated in the feldspathic fraction (F) of the conglomeratic variety; (Q) are predominantly quartz rich fractions. From Kaz mineralization occurrence.

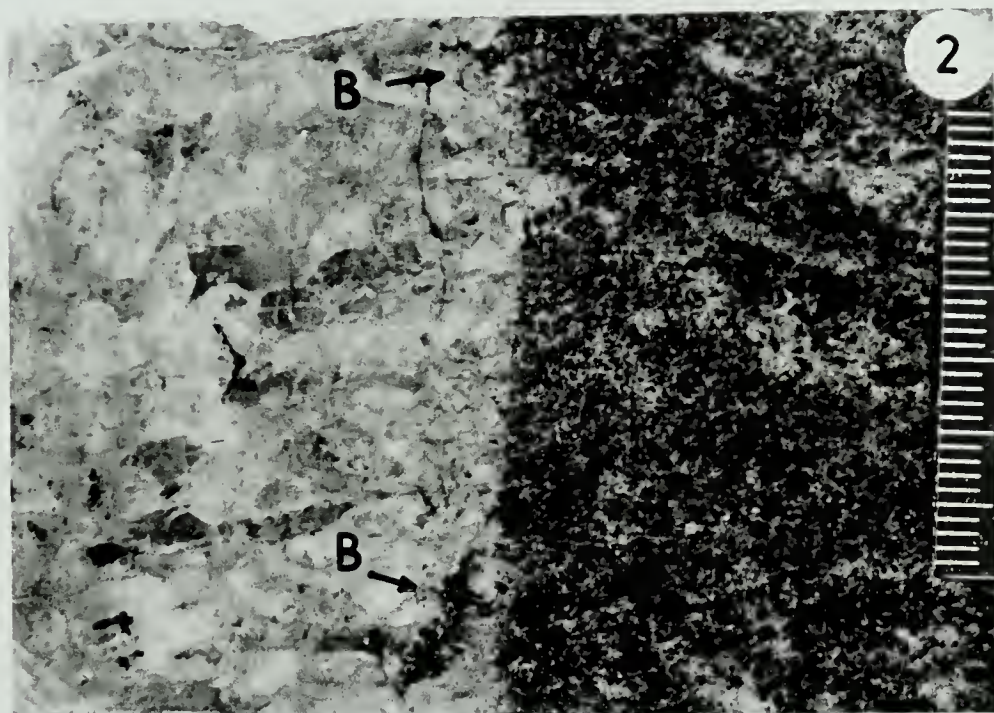


PLATE IV.

Plate V

1. Biotite Gneiss (map unit B). Distinct colour layering associated with the laminated variety of this rock type. Banding may be inherent from original bedded nature of rock (?).
2. Biotite Gneiss (map unit B). Faint layering common to this rock type. Usually this layering is not evident on the outcrop. The layers are accentuated by concentrations of opaque minerals in these bands.

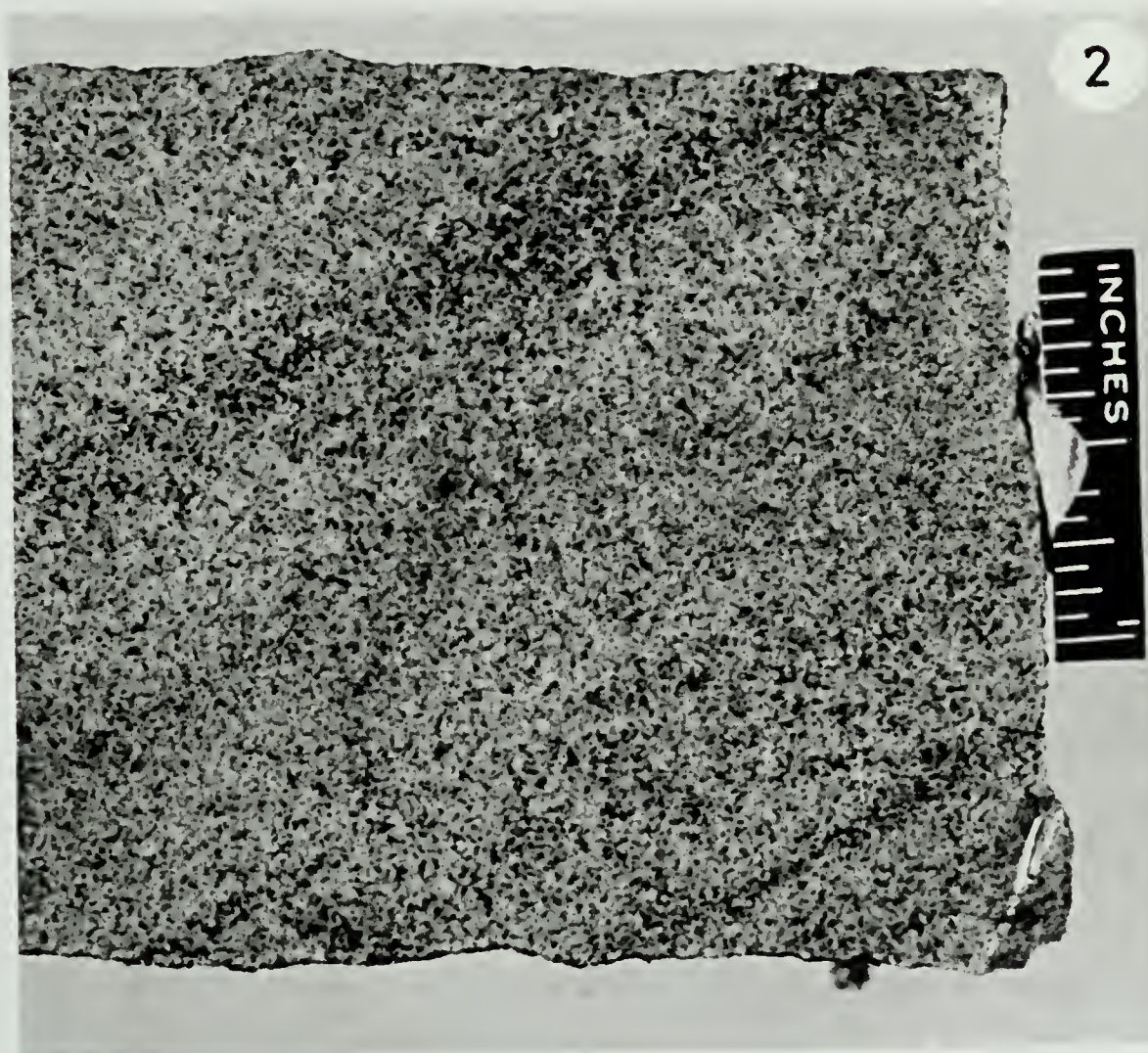
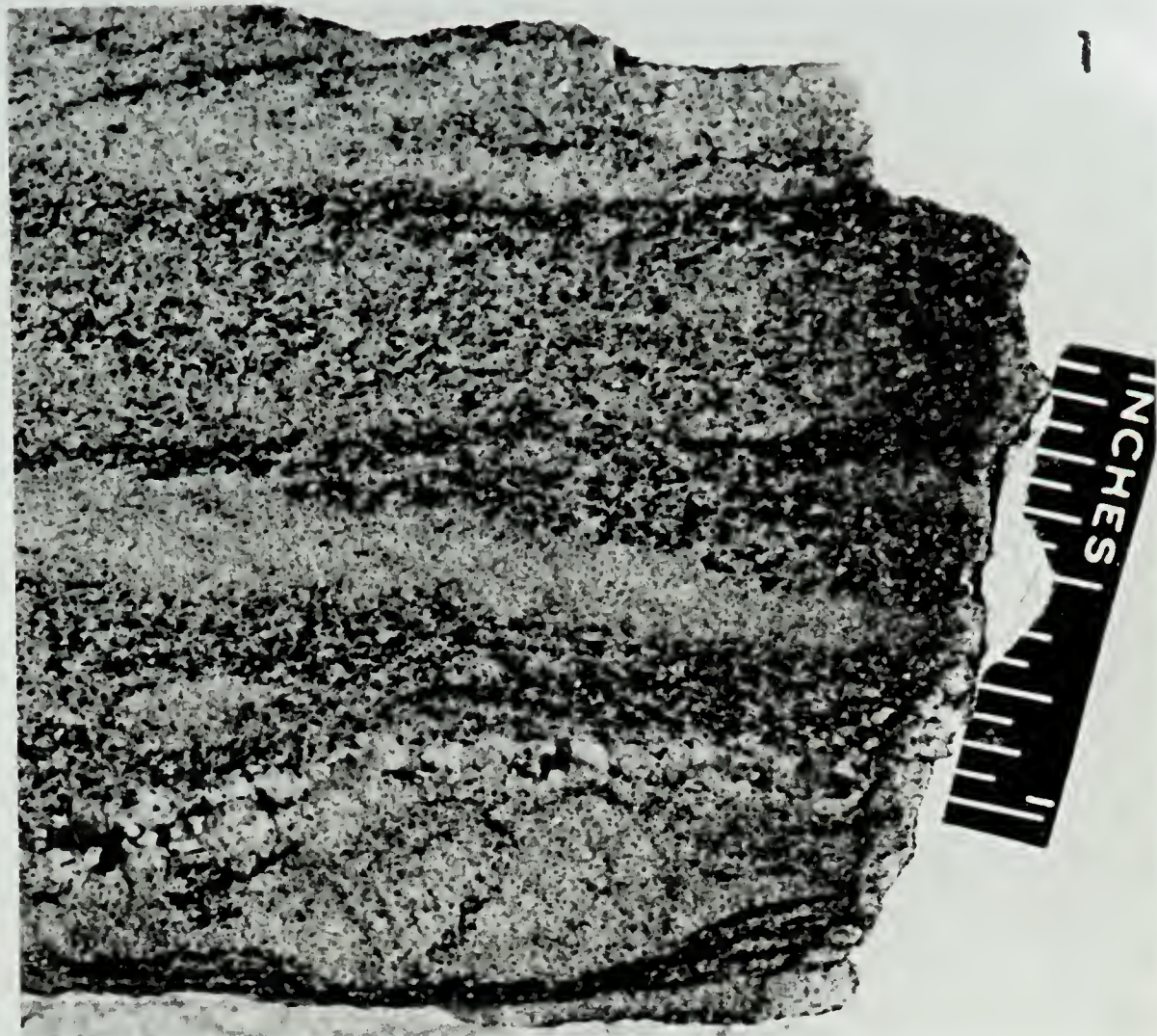


PLATE V.

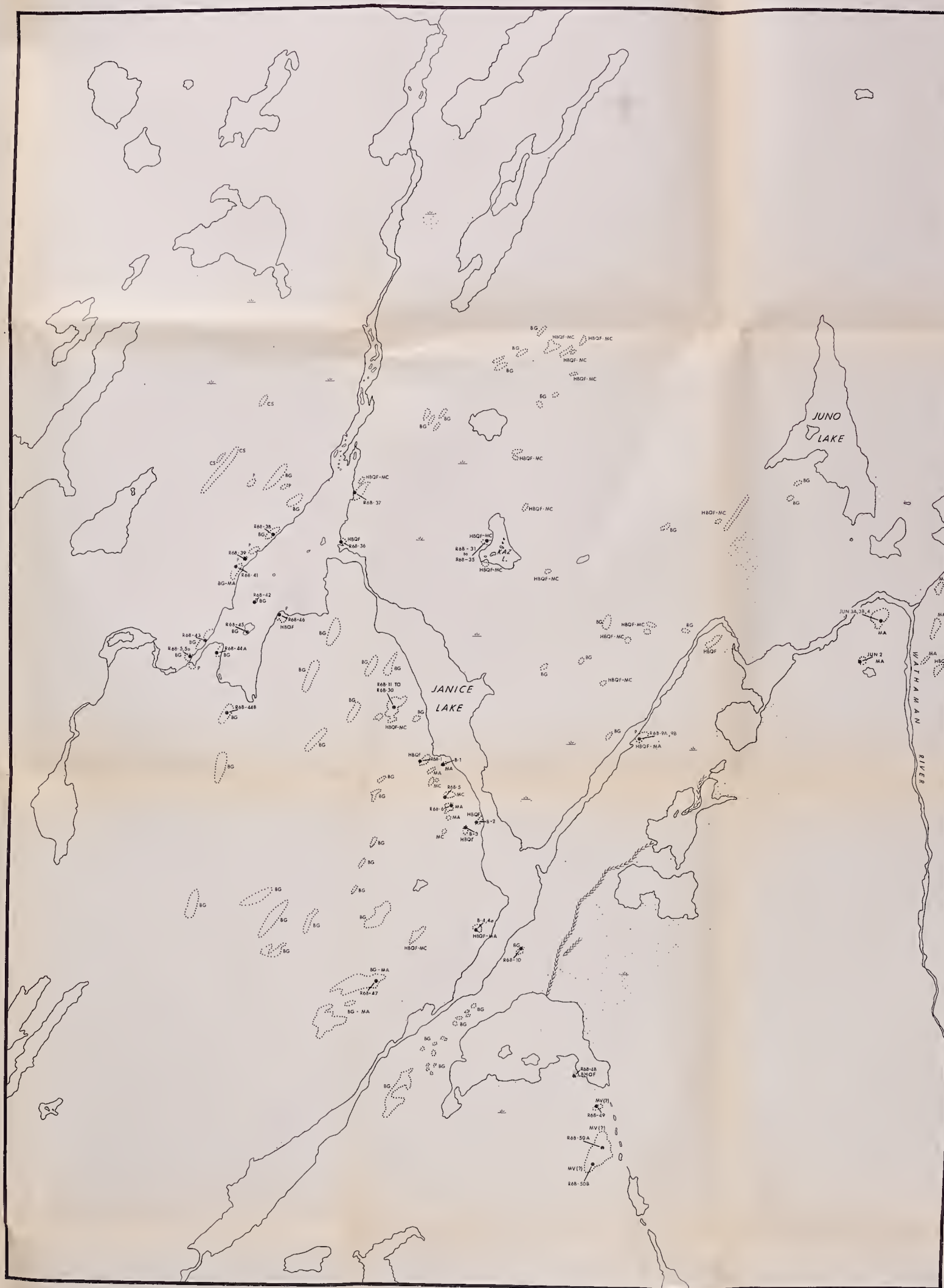


Precambrian

P	Pink pegmatite and oplite
CS	Buff weathered melanocratic, fine grained calc-silicate gneiss with interlayered biotite - hornblende gneiss
BHGF MC	Pink to buff weathered, dark colored arkosic meta - conglomerate associated with hornblende - biotite gneiss, minor meta - arkose and quartzite
BG	Buff weathered, in part color banded biotite gneiss, quartzo - feldspathic rocks minor amounts of hornblende - biotite gneiss, meta - arkose, and quartzite
MV	Black weathered, fine grained, hard meta volcanic (?), (MV), interlayered with dark pink biotite - hornblende gneiss, (BHGF), Relationships uncertain.
MA	Laminated, dark pink to buff weathered meta - arkose and affiliated quartzo - feldspathic rocks. Relationships uncertain.

SYMBOLS

●	Specimen location
	Area of outcrop and associated rock description
R68-1	Hand specimen number and associated thin section number
P	Minar pegmatites
	Areas of heavy glacial overburden
	Swamp
	Esker



JANICE LAKE AREA

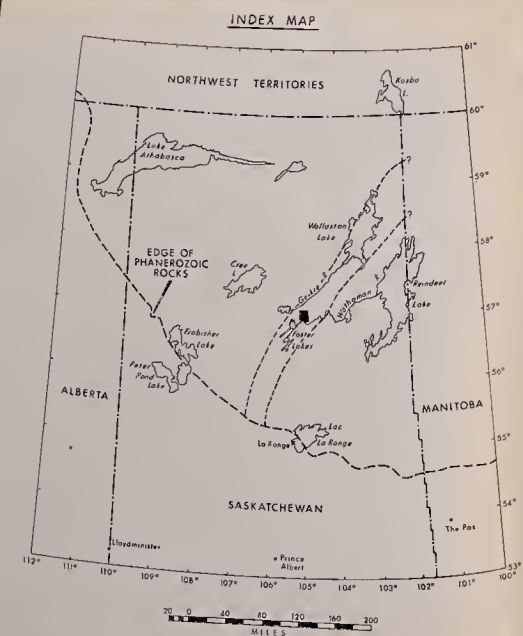
SASKATCHEWAN

OUTCROP AND SPECIMEN LOCATION MAP



Geology by U. Rath, 1968
After reconnaissance mapping by
Pyke and Vopni, 1967.

Base map prepared from aerial photographs
 Approximate magnetic declination 19° East.





LEGEND

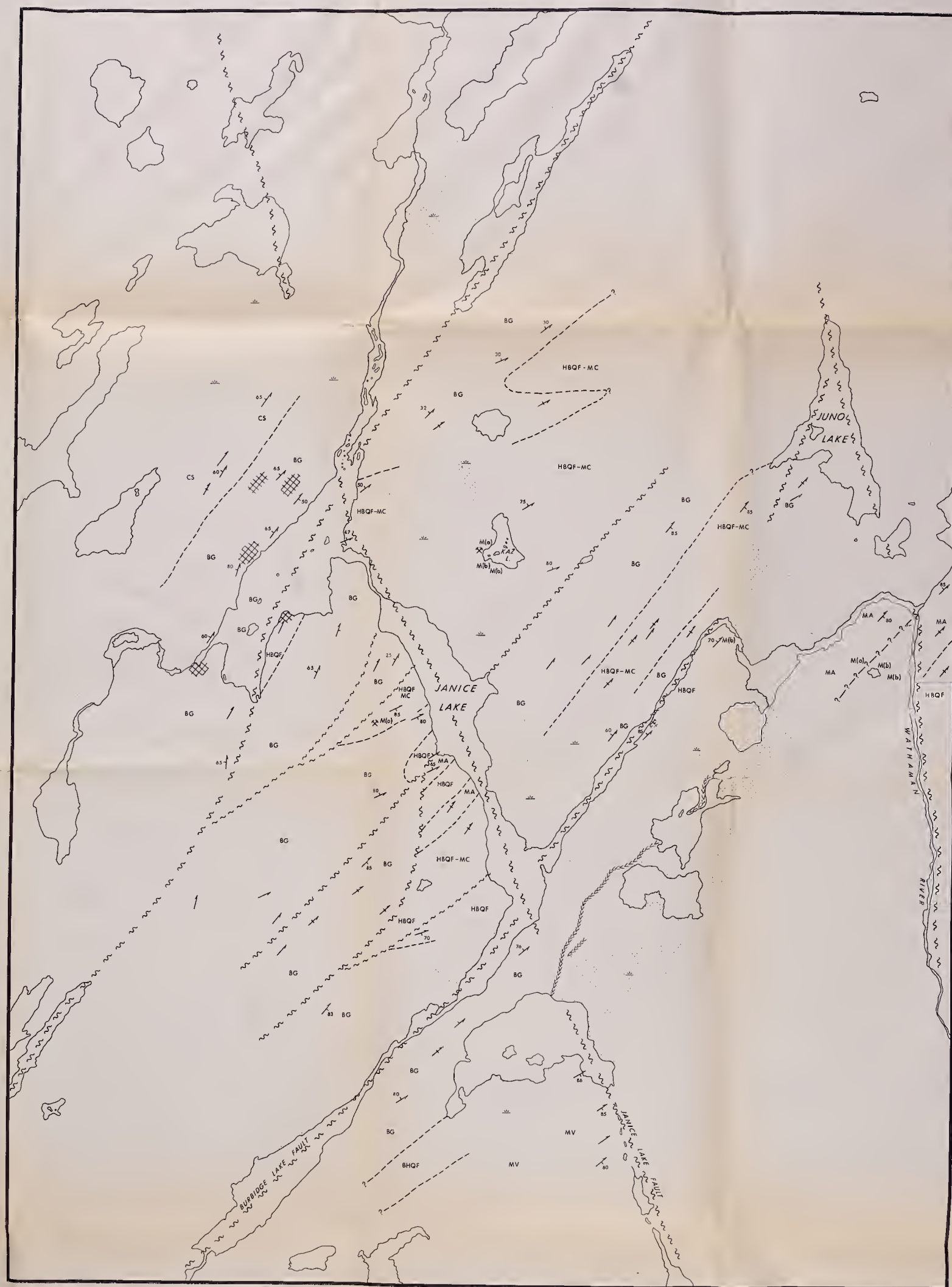
Precambrian

- P** Pink pegmatite and aplite
- CS** Buff weathered melanocratic, fine grained calc-silicate gneiss with interlayered biotite-hornblende gneiss
- HBQF** Pink to buff weathered, dark colored arkosic meta-conglomerate associated with hornblende-biotite gneiss, minor meta-arkose and quartzite
- BG** Buff weathered, in part color banded biotite gneiss, quartz-feldspathic rocks minor amounts of hornblende-biotite gneiss, meta-arkose, and quartzite
- MV** Black weathered, fine grained, hard meta-volcanic (?), (MV), interlayered with dark pink biotite-hornblende gneiss, (HBQF). Relationships uncertain.
- MA** Laminated, dark pink to buff weathered meta-arkose and affiliated quartz-feldspathic rocks. Relationships uncertain.

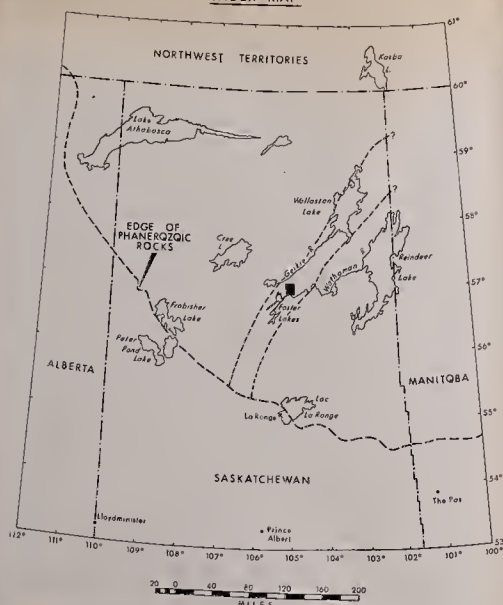
SYMBOLS

- Foliation and/or Gneissosity
- Area of numerous pegmatites
- Approximate fault **
- Assumed fault **
- Areas of heavy glacial overburden
- Swamp
- Esker
- Approximate geological contact
- M(b)** Mineralization found in balders of "Janice Lake" type lithology
- M(o)** Mineralization in outcrop
- Trench

** Recognition of faults was based on a combination of topographic impression and textural variations of adjacent rock units. Where possible magnetic interpretations (Map 2789G, 2790G) after Watanabe (1965) were applied



INDEX MAP



JANICE LAKE AREA

SASKATCHEWAN

STRUCTURE AND LITHOLOGICAL UNITS



Geology by U. Roth, 1968
After reconnaissance mapping by
Pyke and Vopni, 1967.

Base map prepared from aerial photographs
Approximate magnetic declination 19° East.

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